LOAD MODELLING FOR POWER FLOW AND STABILITY STUDIES

by

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to the

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CERTIFICATE

It is certified that the work contained in the thesis entitled **LOAD MODELLING FOR POWER FLOW AND STABILITY STUDIES** by Mr T P Varada Rajan (Roll No 9610459) has been carried out under my supervision and that this work has not been submitted elsewhere for a degree

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T P Varada Rajan

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ABSTRACT

This work aims to incorporate load characteristics in power flow and stability studies A computer code has been developed for modelling various kinds of loads It gives real and reactive powers of different loads for specified voltage and frequency This code has been linked with a power flow program the composite program with some addition facilities is named ' LOADMOD

LOADMOD consists of two main parts namely Load Flow Part (LFP) and Load Modelling Part (LMP) In LMP facility is given to the user to define a number of models, their parameters choice of buses for load modelling to be applied, and distribution of load among defined models Compensation at the load buses is also modelled Real and reactive power loss in the feeders have been modelled, for which the initial real and the reactive power losses at the reference voltage and frequency are needed LFP interacts with LMP, i e LFP gives voltage magnitudes at different buses to LMP, LMP calculates P and Q and gives them as input to LFP and so on till voltages converge

LOADMOD has been tested on NREB (357 bus) and IEEE (30 bus) systems with some assumed load mix at some chosen buses Substantial changes in the final voltages was observed with respect to the results for direct specification of real and reactive powers at load buses Facility has been provided in LOADMOD to iteratively increase the loading by a fixed factor at specified or all load buses in the system, at the end of each LFP+LMP run till LFP fails to converge This failure to converge indicates that the system has reached the static stability limit Changes in the voltages have been studied with increasing loading for the IEEE 30 bus system in order to capture the buses prone to voltage instability

Facility has been provided in LOADMOD for load and generator outages when the loading on the system is increased The results for such contingencies in IEEE 30 bus system have been studied

Chapter 1

Introduction

1 1 Requirement of load modelling

Electric power systems consist of generation transmission and load systems The performance of power systems is generally studied by simulations wherein mathematical equations of different parts are formulated, linked properly and then solved These mathematical equations form the models for the corresponding parts of the power sys tem Till 1980 s generation and transmission systems were represented by mathemati cal equations of different degrees of complexity but loads were generally represented by constant real and reactive powers This representation was satisfactory in most cases of load flow and transient and dynamic stability analysis When the power systems became large and complex and the demand situation forced operation of the power network under heavily loaded condition, the simulated and measured values differed significantly especially with regard to voltage levels, and in some cases system collapses could not be explained as the simulation showed the safer side whereas the actual sys tem exhibited abnormal behaviour In such cases it becomes important to incorporate load behaviour in static as well as dynamic simulations Proper load modelling is thus important, especially in mid term and long term stability studies

1.2 Background of this work

The effect of load characteristics on dynamic performance of power system was known long back in 1930's [1]. Then in 1960's there was work on incorporating voltage dependence of loads and by 1982 much work was reported on load representation [1]. A problem with load modelling is, the loads are diverse and no single standard model can adequately represent different kinds of loads. Furthermore, the actual load mix in an area and load magnitudes are not easy to ascertain. In mid 1980's Electrical Power Research Institute of USA (EPRI) took a step to promote work on load modelling. General Electric Company of USA was awarded a project for developing software for load modelling. GE used the load models that were available till date and developed a computer package called LOADSYN [2]. In the 1990's IEEE task force on load representation gave suggestions on standardizing some of the load models [4, 5]. There have been extensive discussions regarding various aspects of load modelling in the literature, [9, 10, 11, 12, 13, 14, 15, 16, 17, 18].

1.3 Present work

This work is on the same lines as done by GE. A package named "LOADMOD" has been developed in which the various models available have been incorporated and linked with a power flow program for the purpose of power flow analysis. Facility has also been provided for static stability study.

Static load model parameters of different loads have been taken from [3] and from suggestions in [1, 4, 5]. Computer code has been written for dynamic model of induction motor. Classical model of induction motor was considered [6].

Some load modelling concepts are discussed in Chapter 2. In Chapter 3 program development, the features provided to the user to study voltage profiles with increasing load and other features incorporated are discussed. Test cases are considered and the

corresponding results are given in Chapter 4 Chapter-5 concludes with discussion, strengths and limitations of this program and suggestions for future work

Appendix A gives the computer code in FORTRAN for the load modelling part (LMP) of LOADMOD In Appendix B the mathematical background of dynamic model of induction motor is given, and its code is given in Appendix C The input and output files of LOADMOD are given in Appendix D

Chapter 2

Load modelling concepts

The concepts of load modelling and the ways and means of modelling are discussed in several papers and books [2 3, 4 5] In this chapter some of them and those applied to the present work are discussed

Load modelling is considered in two main approaches, namely *Measurement based approach* and *Component based approach*

2 1 Measurement-based approach

In measurement based approach measuring devices are placed at the load buses that are to be represented These devices measure the variation in load active and reactive powers and the corresponding changes in voltage and frequency, (either due to intentionally created disturbance or naturally occurring) From these measurements, the aggregated parameters of the model for the total load at the bus are derived

The advantage of this method is that it gives the aggregated load model parameter of the actual system directly But it has the following disadvantages

- Cost of the measuring equipment may be significant

- There is need to make measurements at all buses which are to be represented, because the loads at different buses generally have different load patterns and mix If two buses have similar loads then measurements at one bus are sufficient and the same parameters can be applied to other

- As the load mix changes at different times of day and seasons continuous measurement under these varying conditions is required

2 2 Component-based approach

In component based approach detailed modelling is done for all or important components of loads Then either the model parameters are aggregated to get one load model or they are used independently In this work they are used independently i e , each mathematical model for a component at a bus is activated by giving voltage and frequency inputs which give the real (P) and reactive (Q) power outputs Then the P and Q outputs of all models are added to get the total load at the bus

This method overcomes some of the disadvantages of the previous methods Thus,

- By changing the mix of the load, the load characteristics may be changed to suit the particular load mix at a given time or to suit seasonal changes

- No hardware is required, only software is needed to be implemented

The disadvantages of this approach are,

- As the loads are diverse, data collection regarding the number of load components and load composition is the main problem

- New load models are to be worked out and implemented when new or redesigned equipment is installed

- More computational time is needed

For Indian conditions where it becomes difficult to make measurements on the system measurement based approach is difficult to be tested and implemented The component based approach is better suited With sufficient statistical data on how the load mix changes in different areas at different times and seasons this approach is expected to give satisfactory results with less cost and problems as compared to the measurement based approach

For the survey of load mix and their changes with seasons EPRI used consumer bill data Similar studies can be done to obtain this data and implement it for Indian conditions

The load model is of two types, namely, static and dynamic

2 2 1 Static load modelling

In the static load model the real and reactive powers at any instant of time are expressed as functions of bus voltage and frequency at that instant

All load components can be represented by static models Examples of load components are lighting, heating, motor loads , air conditioning, arc furnace electrolysis, etc

Static models are of many types [2 3, 4, 6] The most common among them are

- Constant impedance load model
- Constant current load model
- Constant power load model

Polynomial load model

In polynomial load model load active and reactive powers are expressed as

$$P = P_0[A(\frac{V}{V_0})^2 + B(\frac{V}{V_0}) + C] \tag{2 1}$$

$$Q = Q_0[D(\frac{V}{V_0})^2 + E(\frac{V}{V_0}) + F] \tag{2 2}$$

similarly, P and Q can be expressed as functions of frequency with (f/f_0) replacing (V/V_0) in the above equations and different constants

Here P_0 and Q_0 are the values of P and Q at nominal values of V and f i e at V_0 and f_0 P and Q are the values of active and reactive power of the load at any V and f

This model is also called the ZIP model [6] as the earlier three models can be achieved from this by setting some of its constants equal to zero

For example, in equations 2 1 and 2 2, if B, C, E and F are zero then it becomes a constant impedance model Similarly other models can also be achieved Hence polynomial model is a combination of the earlier three models and can give load P and Q in between the results of the constant Z, I or P models

Exponential load model

In exponential load modelling, load active and reactive powers are expressed as

$$P = P_0(\frac{V}{V_0})^P \tag{2 3}$$

$$Q = Q_0(\frac{V}{V_0})^Q \tag{2 4}$$

Similarly, they can be expressed for frequency dependency Sometimes two or more terms with different exponents are used

If some equipment behaves in a particular way for a particular range of voltage and in some other way beyond that range it can be easily incorporated in the exponential

model scheme by having two exponents one for each range as

$$P = P_0(\frac{V}{V_0})^{P\,1} for V_1 \leq V \leq V_2$$
$$P = P_0(\frac{V}{V_0})^{P\,2} for V_2 \leq V \leq V_3$$

The number of ranges can be more than two This feature can be incorporated for the polynomial model also but it would require more number of model parameters

In this work the exponential model is used for static modelling The data for various models were taken from Taylor [3]

In the equations below parameter nm represents the fraction of the total equipment load that is motor Equation 2 5 and 2 6 below are used when the equipment is either fully motor or not at all whereas equation 2 7 and 2 8 are used when the equipment contains some part as motor as in heat pumps etc

For nm=0 0 or nm=1 0

$$P = P_0[(\frac{V}{V_0})^{P}\ (\frac{f}{f_0})^{P_f}] \tag{2 5}$$
$$Q = Q_0[(\frac{V}{V_0})^{Q}\ (\frac{f}{f_0})^{Q_f}] \tag{2 6}$$

For $0\ 0 < nm < 1\ 0$

$$P = nmP_0[(\frac{V}{V_0})^{P}\ (\frac{f}{f_0})^{P_f}] + (1 - nm)P_0[(\frac{V}{V_0})^{P\ nm}(\frac{f}{f_0})^{P_f\ m}] \tag{2 7}$$
$$Q = nmQ_0[(\frac{V}{V_0})^{Q}\ (\frac{f}{f_0})^{Q_f}] + (1 - nm)Q_0[(\frac{V}{V_0})^{Q\ \ m}(\frac{f}{f_0})^{Q_f\ m}] \tag{2 8}$$

In the above equations,

P = Bus real power as given by the model

Q = Bus reactive power as given by the model

P_0 = Initial real power at rated voltage and frequency

Q_0 = Initial reactive power at rated voltage and frequency

P_v = Voltage dependent exponent of real power

Q_v = Voltage dependent exponent of reactive power

P_f = Frequency dependent exponent of real power

Q_f = Frequency dependent exponent of reactive power and

P_{vnm} Q_{vnm} P_{fnm} and Q_{fnm} are the voltage and frequency dependent exponents of active and reactive powers respectively of non motor part of load

The procedure followed in this work is that the load at the bus is divided among the defined models (for which the parameters of exponential models are available) i e P_0 for each model is given From P_0 and power factor reactive power Q_0 is calculated The model is activated by the V and f inputs where V input is obtained from Load Flow Program and f is calculated from the frequency regulation characteristics of the system Equations 2 5 2 6 2 7 and 2 8 are used to calculate P and Q from the input V and f values

Similarly, this procedure is repeated for all the models and their corresponding real and reactive powers are obtained Individual P's and Q s are then added to get the total P and Q of the load at the bus for the given V and f Then the feeder real and reactive power losses are added to P and Q which completes the P and Q calculations at the bus for given V and f Because of varied voltages the line P and Q losses also vary The implementation of this is discussed in the later part of this chapter

In EPRI LOADSYN, the individual load model parameters are aggregated and one load model is obtained in which the compensation at the bus is also included In this case when the aggregated load reactive power is equal to the compensation the Q_0 in the equation 2 6 and 2 8 become zero This causes a problem since, the bus reactive power is calculated to be zero To avoid this problem LOADSYN normalises the reactive power formula to P_0 instead of Q_0 In the present work as each load model is treated independently and at the end compensation, if any is added, the above problem does not arise

With good models and accurate load mix representation, static load models, when used for static or dynamic simulations give better results than the the conventional constant P, Q models When LOADSYN was tested on Ontario hydro system with

only static models significantly improved results were obtained [2]

When static models are used for large dynamic loads such as induction motors their dynamic behaviour may not be captured accurately The static models of such loads give inaccurate results It then becomes necessary to accurately model the dynamic behaviour of the equipments

2 2 2 Dynamic load modelling

In the dynamic load model, the real and reactive power at any instant of time are often expressed as functions of bus voltage and frequency at the previous instance of time in the discrete time representation of system dynamics Alternatively in the continuous time formulation an appropriate differential equation may be used for load dynamics The components in the power system that require dynamic modelling are

- Induction motors
- Thermostat control of space heating and refrigeration equipment
- Load tap changing effect of transformers
- Over current protection of big induction motors
- Synchronous motors
- Arc extinction and restart of discharge lamps

The extent to which these need to be modelled depends on the type of study to be done Generally, since most dynamic loads are induction motors, their modelling has been discussed extensively [2 5 6]

In the present work, classical induction motor equivalent circuit is taken and the swing equation (differential equation) is solved using Runge Kutta method The mathematics of this is given in Appendix B and its computer code is given in Appendix C

If all the dynamically behaving equipments in the system are modelled properly then accurate results will be obtained and probably all cases of voltage collapses would be explained properly

2 3 Modelling compensation

Generally at load buses reactive power compensating equipment is present This compensation varies with change in voltage at the bus

AT 1 0 p u voltage i e for $V_1 = 1\ 0 p\ u$ at the bus the reactive power injection Q_1 at the bus for fixed capacitive shunt compensation is

$$Q_1 = {V_1}^2 y \tag{2 9}$$

When the bus voltage changes to V_2 we have

$$Q_2 = {V_2}^2 y \tag{2 10}$$

From equation 2 9 and 2 10

$$\frac{Q_2}{Q_1} = \frac{{V_2}^2}{{V_1}^2}$$

$$Q_2 = {V_2}^2 \frac{Q_1}{{V_1}^2}$$

In equation 2 9 $V_1 = 1\ 0 p\ u$ so that $Q_1 = y$

$$Q_2 = {V_2}^2 Q_1 \tag{2 11}$$

Equation 2 11 is implemented to get the compensation at any voltage

2 4 Modelling real and reactive feeder losses

Let the initial real power loss in the feeders at 1 0 p u voltage at the terminal of the load be specified

Let R = resistance of distribution line This is a fixed quantity Then the real power loss on the distribution line is

$$L_1 = {I_1}^2 R$$

(2 12)

or

$$L_1 = \frac{{S_1}^2}{{V_1}^2} R = \frac{{P_1}^2 + {Q_1}^2}{{V_1}^2} R \qquad (2\ 13)$$

Where P_1 and Q_1 are load real and reactive powers at 1 0 p u voltage at the terminals of the load

Let the losses at the changed voltage V_2 be L_2

Then

$$L_2 = \frac{{S_2}^2}{{V_2}^2} R = \frac{{P_2}^2 + {Q_2}^2}{{V_2}^2} R \qquad (2\ 14)$$

P_2 and Q_2 are obtained from static load modelling From equations 2 13 and 2 14

$$\frac{L_2}{L_1} = \left(\frac{{S_2}^2}{{V_2}^2}\right)\left(\frac{{V_1}^2}{{S_1}^2}\right)$$

$$L_2 = \frac{L_1}{{V_2}^2}\left(\frac{{S_2}^2}{{S_1}^2}\right)$$

$$L_2 = \frac{L_1}{{V_2}^2}\left(\frac{{P_2}^2 + {Q_2}^2}{{P_1}^2 + {Q_1}^2}\right) \qquad (2\ 15)$$

Equation 2 15 is implemented for the losses at any voltage

Similarly, if the initial reactive power loss at 1 0 p u voltage at the terminal of the loads or the reactance of the distribution line is known, Q_{loss} can be calculated at any voltage and the same equation 2 15 can be applied, where, in this case L_2 would represent Q_{loss} under various conditions of load This modelling of real and reactive power loss by equation 2 15 has been implemented in LMP Flexibility is given to the user to choose an option to use this facility

In the system because of the drops in R and X of the distribution lines the actual voltages at the load component is less than that at the bus If P_1 and Q_1 are the real and reactive powers of load at 1 0 p u voltage it implies that the voltage at the component is 1 0 p u The bus voltage will not be 1 0 p u because of line drops However, in calculating P_1 and Q_1 the distribution line drops have been neglected Hence the actual P and Q of loads are not equal to P_1 and Q_1 calculated neglecting line drops An iterative procedure can be developed to accurately incorporate line drops and losses This, however has not been done since, if the links are strong enough, reasonably accurate results are expected without resorting to iterations However in future this can be taken up to modify LMP to get more accurate results The computational complexities will, however increase

India has large agricultural loads A major component of these loads are induction motors, fed from long distribution lines, because of which line drops are high This implies that the approximate formulae derived earlier for line loss calculation may be unsatisfactory for agricultural loads Hence accurate modelling of load as well as drops in lines may be required in the Indian context

In the present work, static model parameters are taken from Taylor [3] Though these parameters are relevant for Indian conditions, there are aspects of Indian loads which are unique For instance, the large scale use of small uninterrupted power supply units by commercial and domestic users, stems from frequent power breakdowns and announced power cuts Load modelling should incorporate such units There may be aspects in dynamic loads which are peculiar to India There is thus need for considering the character of loads in India in detail and developing new and relevant models both static and dynamic The scope of the present thesis however, does not include such a study

Load modelling when observed from these angles is a vast field and gives much scope for further work This component based approach would be most successful when load statistics are properly known It is cost effective By simple variation in input data files

the computer program for load modelling can be made suitable to any system

In the next chapter the flexibilities provided in LOADMOD and the implementation of the program are discussed The main program with all the data files required is given in a floppy disc with this work

Chapter 3

Programming details

3 1 Introduction

In this chapter the load modelling program and the details of its linking with the load flow program are discussed The code written in FORTRAN 77 is given in Appendix A

The load flow part has one input data file 'lfdata' whereas load modelling part has several input data files whose details are explained in the following sections The LOADMOD with all input data files and the code are given in a floppy disc with this work In the file named 'information' all the data files required are listed An information file is given with each input data file which has the same name as the data file with an extension ' inf For example, the data file 'gen outage has information file named gen_outage inf'

The load modelling part is divided into four modules which are appropriately linked with the load flow part The LFP used is a Newton Raphson load flow program in polar co ordinates using sparsity technique

The details of the modules and their linking with load flow program are discussed in the following sections The flow chart of the LOADMOD is shown in Figure 3 1

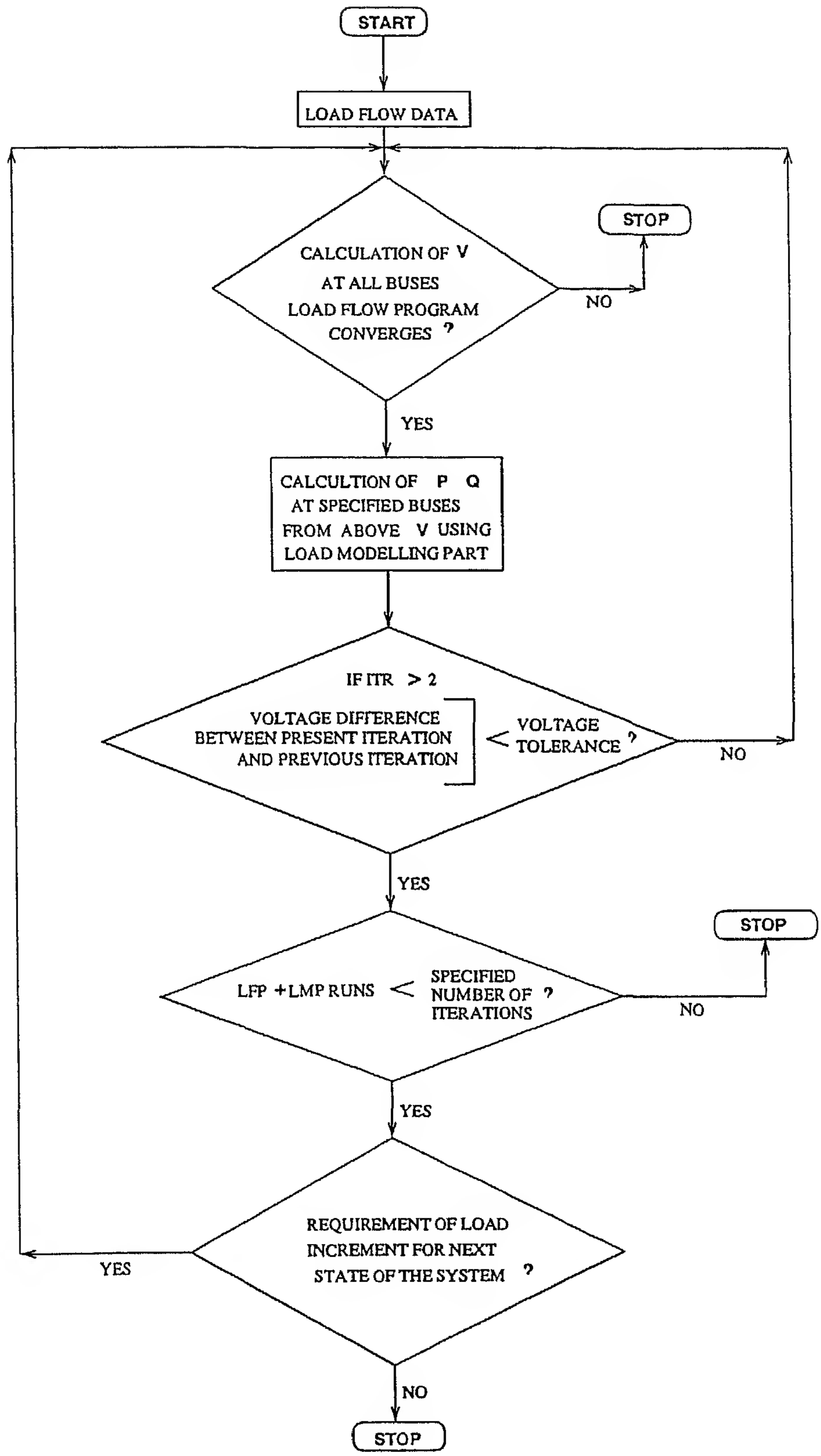


Figure 3 1 LOADMOD flowchart

3 2 Module - 1

Module 1 essentially serves two basic purposes First all the variables used in LMP are declared Secondly some of the input and output files required for LMP are opened This module appears along with the declarations of the Load Flow Part The details of some of the main variables which are used for linking of LFP and LMP are discussed in detail in the next modules

3 3 Module - 2

This module stores the compensation, if any, at the load bus in an array 'qq(bus number) which is subsequently made use of in the Load Modelling Part This module is placed in the Load Flow Part where the data for the load buses is read

3 4 Module - 3

This module is placed after all the data required for the Load Flow Part is read This module reads the data needed to provide flexibility to LOADMOD The input files which are read by this module are as follows

3 4 1 File 'itr_limit'

This file sets limits in the iterations of

- LFP
- LFP+LMP convergence

Flexibility has been provided to either keep the value of voltage tolerance constant irrespective of number of iterations or to change the tolerance after some required number of iterations of LFP+LMP runs

3 4 2 File 'gen_outage'

This file stores the information regarding generator outages which are as follows

- Whether generator outage is required or not
- Number of generators
- Generator bus numbers
- The load increment iteration after which the generator is to be taken out

3 4 3 File 'load_outages'

This file contains information similar to that in 'gen_outage'

3 4 4 File 'out_plot' and 'out_plot_names'

These files facilitate LOADMOD to generate individual output files for each bus in which the bus voltage and P and Q values at the bus throughout the different states for the system (i e , system states at the end of each LFP+LMP convergence) are written for easy checks and plotting The choices to be given in these files are

- Option for using this facility
- Selection of *all* or a *limited* number of buses If *all* option is chosen, then LOAD MOD generates output files for each bus with a default file name 'o bus number'

for which it uses file out_file_names to store the default generated file names If *limited* option is chosen the bus numbers and the required file names are to be specified in file out_plot Data for all the options are read from this file

3 4 5 File 'load_mix_change'

This file provides the option for changing the load mix from one state of the system to the next Once this facility is opted for then the following data are read from the file

- buses at which the load mix change is required
- the models where the loads change
- the amount of load mix change

3 4 6 File 'react_loss'

The loads at the buses are fed through distribution feeders because of which there is a reactive loss in the lines This Q loss depends on the square of the current which in turn depends on the apparent power of the load The loads change with change in bus voltages For modelling Q loss and taking it into account while calculating the Q injection at a bus the data required is the reactive power loss on the distribution feeders assuming 1 0 p u voltage at the terminal of the load This data i e the bus numbers and the Q loss at the bus are read from this input file

3 4 7 Files 'load_modelling' and 'load_composition'

For modelling real and reactive losses in the feeders at the bus equation 2 15 is used In this equation S1 represents the total apparent power of the loads at 1 0 p u voltage (at

the terminals of the load) This calculation of S1 at each bus is done here and stored in an array s1(bus number) for which the inputs required are

- Bus number at which load modelling is applied
- The total real power of load at these buses
- The load composition at these buses

The first two requirements are read from file load_modelling and the third from file load_composition Then the load model subroutine model is activated which implements the load model characteristics and gives the total real power of the modelled load in variable p11' and reactive power in variable 'q' These values of p11 and 'q are stored in a complex array 's1(bus number) The details of the subroutine model are discussed in a later section

At the end of this module two variables are used i6 and i2 At the end of each LFP+LMP run the execution is transfered to statement labeled 899 and variable 'i2 keeps track of the iteration number i e , the number of iterations executed in the execution of the LFP+LMP run for one setting of load When the difference in bus voltages of present and previous LFP+LMP runs is less than the tolerance limit this process is stopped and the system power level is increased for next state of the system and the execution is transfered to statement labeled 8980' This is called load increment iteration and is tracked by variable i6

3 5 Module - 4

This forms the major part of LMP in which

- Data transfer between LFP and LMP occurs
- Load characteristics are implemented

- Real and reactive losses are modelled
- Options specified in Module 3 are implemented
- Sequence of operation of LFP and LMP are controlled

This module is placed just at the end of the Load Flow Program The following steps describe the operation of this module

3 5 1 Step - 1

The buses at which loads are to be modelled are read into an array bn and their corresponding real powers into an array 'bpwr

3 5 2 Step - 2

If the option for load mix change is chosen then the following data is read from the file load_mix_change', for that state of the system

- The buses at which the load mix is to be changed
- Model numbers at which the loads are to be changed for each bus
- The change in the model load for each bus

3 5 3 Step - 3

Each bus is considered one by one and the load model characteristics are implemented taking into account changes in the load mix and load outages as described in the fol lowing points

- The bus voltage is transfered from LFP (variable x') to LMP (variable v) Frequency f and time step t which are read from file load_composition are kept constant In this work the frequency changes are not implemented as they are not as important as voltage changes This can be done in a straightforward manner if the frequency the frequency regulation characteristics of the system is implemented When used with a stability program the values of f and t are fed from it

- With the above information the subroutine model' is activated which implements the load model characteristic and real power loss modelling Subroutine model' gives modelled real and reactive powers (including the real losses related to the bus) as its output in two variables p and 'q The details of the subroutine 'model are dealt in detail later

- The variables p' and 'q' are transfered to variables pload' and qload' which are used in LFP for real and reactive powers of the loads

- The compensation at the load bus (variable 'qq' in module 2) is modelled using equation 2 11 and added to variable qload'

- Reactive power loss in the feeders is modelled using the equation 2 15, and is added to the variable 'qload' With this the calculation of P and Q at the bus is complete

- The LFP gives its real and reactive power injection outputs in the variables 'pinj and qinj' The output of the modelled load at the specified buses is transfered back into 'pinj' and 'qinj'

- The voltage values and real and reactive powers at the buses where the load modelling is applied, are written into a file 'itr out2' for each LFP+LMP run

3 5 4 Step - 4

This step checks for the convergence of LFP+LMP runs The actual operations in this step are as follows

- The voltage of all the buses obtained from LFP are stored in an array xl1 From the second iteration onwards (of LFP+LMP run) the present voltages are compared with the previous iteration voltages (xl1) and the maximum value of the difference is stored in variable xx3
- The value in xx3 is compared with the voltage tolerance limit If it is more than or equal to the limit then the control is transfered to the statement labeled 899 for repetition of another LFP+LMP iteration If the tolerance is satisfied LFP+LMP convergence is achieved and further options are implemented
- When the system is over loaded (implying decrease in stability margin), or the tolerance limit is very small a facility is provided to change the voltage tolerance limit to some other value after some iterations of LFP+LMP runs

3 5 5 Step - 5

When LFP+LMP runs converge the bus voltages and the real and reactive power injections at all buses are written into the file 'itr out1' At the end of LOADMOD, this file contains information regarding V, P and Q at all buses for all states of the system

3 5 6 Step - 6

When the LFP+LMP converges for each state of the system, the voltage and real and reactive powers at the bus and total real and reactive powers of the system are written into the corresponding files for the buses as per the option in the data file out_plot'

These output files are used to observe the voltages at the bus for different loadings of the system

3 5 7 Step - 7

Depending on the options in the data files gen outage and load_outage the generators and loads are taken out For load outages P and Q of the loads are made equal to zero For generator outages PGEN PMAX and QMAX are made equal to zero and the variable IFLAG used by LFP to distinguish generator/load/slack bus is changed to make it a load bus Hence from the next iteration this bus is treated as load bus with zero P and Q loads The convention used by the LFP for IFLAG' is

- IFLAG=1 for generator buses
- IFLAG=2, for load buses
- IFLAG=3, for slack buses
- IFLAG=0, for no connection to the bus

3 5 8 Step - 8

For the first state of the system i e when 'i6 is equal to one, the following information is read from the file 'load_increment

- information regarding the options for other states
- the factor of power level increment for the coming states
- the buses where the powers are to be increased

3 5 9 Step - 9

If the power inciement option is chosen then control is transfered to the statement labeled 8989 i e, to the end of Module 3 The LFP+LMP convergence for the next state of the system is taken up

Thus aftei some power increments of the system the voltages at buses start de cieasing and the number of iterations taken by load flow as well as the LFP+LMP to converge, increases This operation is continued till the load flow fails to conveige i e the system reaches the static stability limit

3 5 10 Subroutine - 'model'

The sequence of operations in this subroutine are discussed below

- The bus numbers at which the load modelling is to be applied is transfered to the subroutine 'model
- From the input file 'comp_code', the information regarding the number of models defined are read into a variable no_model'
- The information regarding the load composition (real power at the bus divided among the defined models) is read from the input file 'load_composition', into an array ml(model number)'
- Elements in the array ml' are modified for
  - load increments
  - load outages
  - load mix changes
- Real losses in the feeders catered to by the bus are read from the data file 'load_composition'

- Only the model characteristics at that bus are implemented using a subroutine named modelchar , the details of which are dealt later The information passed to the subroutine modelchar is

  - real power of each model (P_0 of each model)
  - voltage at the bus
  - frequency at the bus
  - time step (used when linked with stability program)

The subroutine 'modelchar gives the modelled real and reactive powers of each model in the arrays realp and 'reactp All the elements in the arrays 'realp' and reactp are added into the variables p' and q respectively which give the total modelled real and reactive powers of all the models at the bus The real power losses in the feeders at the bus are modelled using equation 2 15 and are added to the variable p' This completes the calculation of real power at the bus i e , p injection at the bus The same procedure is repeated for all buses to get the corresponding modelled real powers

3 5 11 Subroutine - 'modelchar'

In this subroutine,

- Option for static (exponential or polynomial) or dynamic modelling of each model is read from file 's_d'
- Parameters requred for different exponential models are read from file 'comp_char'
- The real power and power factor of each model is used to calculate the reactive power
- Equations 2 5, 2 6, 2 7 and 2 8 are used to obtain the modelled real and reactive power loads of each model Facility is given to opt for a polynomial model, but

has not been developed in the current program In future work the parameters of the model are to be fed in the file comp_charp' and the mathematical equations are required to be written

Code is developed for dynamic modelling of induction motor and is given in Appendix C This appears in the form of a subroutine dynmodel in LOADMOD Details of dynmodel are discussed below The real power input of the motor model may consist of motors of different range and each range may have a number of motors This information is read in subroutine modelchar from the file d_d' and supplied to the subroutine dynmodel' The outputs from this subroutine are the modelled real and reactive powers of the motor When used with stability program the dynamic model of induction motor requires voltage, frequency and time step These should be supplied by the stability program

3 5 12 Subroutine - 'dynmodel'

- The parameters of the motor of one range read from the input file 'd_d are
  - rated power
  - fraction of the rating at which the motor is used
  - power factor
  - Rs Xs, Xm, Rr and Xr of the equivalent circuit (Figure B 1)
  - inertia constant, H (MJ/MVA)
  - A, B and C values used in equation B 8
- The value of ω_s and ω_m are calculated
  - $\omega_{base} = 2\ 0\pi f_{base}$, $f_{base} = 50\ 0$ Hz
  - $\omega\ = 2\ 0\pi f_s$, $f_s =$ actual frequency
  - ω_m at full load $= \omega_s(1\ 0\text{-slip})$

The values of ω_m at full load (ω_{m01}) are stored in variable 'wm01

- Full load torque is calculated
  - $t_{m0} = \text{power}/\omega_{m01}$
- The parameters of the Thevenin equivalent circuit (Figure B 2) Re and Xe are calculated using equation B 2
- Thevenin equivalent voltage is calculated using equation B 1
- Runge Kutta method is used to solve the differential equation (equation B 9) and the value of ω_m is obtained
- the value of t_m for this value of ω_m is calculated using the equation B 8 appendix B
- From the values of ω_m and t_m the modelled real power is obtained The reactive power of the motor is calculated from this real power and the power factor
- This value of ω_m becomes the initial value for the next iteration of the model

Chapter 4

Results and discussion

In this chapter the application of LOADMOD to study the load flow and static stability of two systems is considered The first system is the system under the jurisdiction of Northern Regional Electricity Board (NREB) of India It is a large system with total load of about 17 000 MW The second system is the IEEE 30 bus system The aim of this study is to do the load flow analysis with static load modelling and to capture the bus voltages with increasing system loading The details of the study are given below

4 1 NREB system

4 1 1 Load flow study for base load condition

In the NREB system load modelling is applied at eleven buses of 220 and 132 K V level The details of the NREB system are shown in Table 4 1 [7]

The buses chosen for load modelling and their real power loads at nominal values of voltages are given in Table 4 2

The real power loads at these buses are divided among the defined models at each

Table 4 1 Details of NREB system

Number of total buses	375
Transformers	155
Lines	438
Z loads	80
PQ loads	166
Cenerators	70
Slack bus	1(Bus No 183)

Table 4 2 Buses modelled in NREB system

BUS NUMBER	P_LOAD(MW)	VOLTAGE(p u)
115	121 08	1 0
134	70 94	1 0
135	19 87	1 0
136	35 00	1 0
152	24 59	1 0
158	41 62	1 0
181	202 48	1 0
243	226 76	1 0
259	247 77	1 0
267	240 66	1 0
282	317 09	1 0

Table 4 3 Results at the end of one LFP+LMP iteration

Bus No	Volt(p u)	P_load	Q_load
115	8744	110 6101	25 4810
134	8382	63 1387	20 2399
135	8050	17 2694	3 1093
136	8472	31 3541	6 1463
152	8680	22 3608	9 7205
158	8582	37 5732	8 7956
181	9636	197 1735	85 6235
243	9712	221 9774	13 8056
259	9842	244 9408	22 4375
267	1 0033	241 2382	39 2232
282	9113	297 7038	28 2234

bus and LOADMOD takes these inputs as the nominal power P_0, of each model at 1 0 p u voltage At the end of one LFP run, the voltages at all buses are calculated and are fed to LMP LMP calculates the values of real and reactive load powers, P_{load} and $Q_{l\ ad}$ respectively at the buses specified where the load modelling is applied The bus voltages and the real and reactive power injections at the end of one LFP+LMP run are shown in Table 4 3

From the above results it is observed that, at bus number 115, the P_{load} calculated by LMP is 110 61 MW instead of the specified value 121 08 MW (Table 4 2) and Q_{load} is as calculated by the load models Similarly, at the other buses shown above the P and Q loads are calculated using the voltages at the respective buses The Q load calculated mainly depends on the load mix data provided, i e , the division of the real power load among the defined models

These real and reactive power loads are given fed to the LFP for another LFP+LMP

Table 4 4 Results at the end of LFP+LMP convergence

Bus No	Volt(p u)	P_load	Q_load
115	9079	113 3142	38 1916
134	9225	67 0958	26 8317
135	9021	18 5186	6 1311
136	9117	32 8464	10 6632
152	9424	23 5933	11 0906
158	8851	38 3063	13 3028
181	9774	199 1684	89 0539
243	9846	224 1940	24 3254
259	1 0046	248 5980	23 4187
267	1 0178	243 7789	33 0406
282	9624	308 7208	61 2777

run The voltage tolerance lımıt for convergence of LFP+LMP runs ıs taken to be 0 005 p u, and ıs ıncreased to 0 01 p u after 5 ıteratıons Thus, when convergence ıs achıeved, the dıfference ın voltage magnıtude at any bus for two consecutıve ıteratıons ıs less than the tolerance lımıt

LFP+LMP convergence was achıeved ın 4 ıteratıons and the end results are gıven ın Table 4 4

From these results, ıt ıs observed that when the bus voltages change the loads change (whıch ıs not taken ınto account ın the conventıonal constant P, Q model), and as the loads change the bus voltages agaın change Thıs ıs taken ınto account ın LOADMOD LFP+LMP runs by exchangıng the voltages and loads and they finally converge to the proper steady state values The amount of change ın the voltages and loads depends on the load composıtıon The final values of voltages and the real and reactıve powers at the modelled buses depend on the load mıx data and the load characterıstıcs avaılable

4 1 2 Static stability study by gradually increasing the system loading

When the LFP+LMP converges and the operating point for that state of the system is obtained the total system power level is increased by a factor of 1 01 i e the following quantities are multiplied by the factor 1 01

- P_{gen}
- P_{load} and Q_{load} at the load buses which are not modelled
- P_0 of all the models at the buses which are modelled

The same procedure as of earlier LFP+LMP runs is followed for getting the load flow for this case Thus the system power level is incremented systematically till the loadflow program fails to converge indicating that the system reached the static stability limit Voltages P and Q loads, at the buses modelled at a state prior to failure of LFP are shown in Table 4 5

The voltage, P_{load} and Q_{load} at the specified load buses (data file out_plot') at different system loading are stored in separate files The voltages at bus 115 are shown in Table 4 6

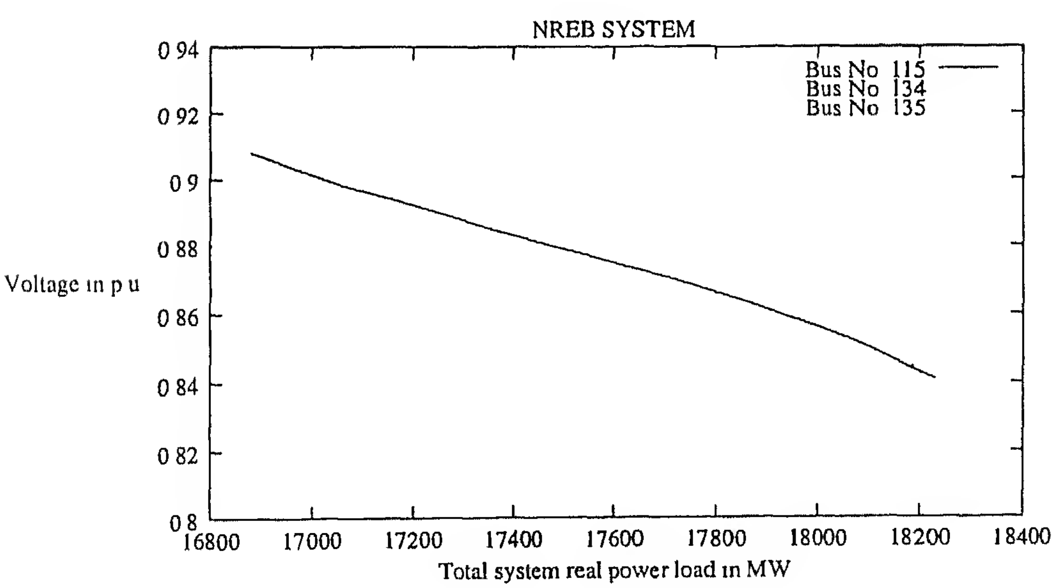
The variation of voltages at buses 115 134 and 135 with the total system real power is shown in Figure 4 1

To capture the voltages close to the stability limit, load increment was done with decreased increments around this point The resulting voltages at buses 115, 134, 135 and 158 are shown in Figure 4 2

By modelling the loads at all buses with accurate load mix data the voltages and loads around static stability limit can be captured accurately, which can be used to study the problematic buses

Tıblc 4 5 Results of the stıte pııoı to the fıılııc of LFP

Bus No	Volt(p u)	P_load	Q_load
115	8406	117 6417	49 3039
134	8394	68 8664	28 8229
135	8118	18 9144	7 6729
136	8183	33 4713	13 6792
152	8648	24 3075	10 4655
158	7895	38 9878	15 4109
181	9623	214 4887	100 9493
243	9558	238 9556	96 9486
259	9571	261 5258	87 0234
267	9837	258 9569	33 2178
282	8907	319 5829	140 8106



Fıguıc 4 1 Voltıges ıt buses 115 134 and 135 wıth system load ıncıement of 1 01

Table 4 6 Voltage P_{load} and Q_{load} at bus 115 at different system loadings

BUS 115					
A	B	C	D	E	F
1	16878 410	4180 284	908	113 314	38 192
2	17043 219	4243 853	899	113 829	42 462
3	17210 053	4307 711	892	114 410	45 443
4	17378 092	4370 181	884	115 012	47 395
5	17547 734	4432 576	877	115 659	48 628
6	17718 354	4494 475	870	116 323	49 348
7	17888 189	4583 042	862	116 902	49 994
8	18059 463	4666 313	853	117 416	49 889
9	18228 732	4745 934	841	117 642	49 304

(This data is stored by LOADMOD in the file name specified by the user in file out_plot)

A	System state number(first one is the base case)
B	Total P_load of the system in MW
C	Total Q_load of the system in MW
D	Voltage at the bus in p u
E	P_load at the bus in MW
F	Q_load at the bus in MW

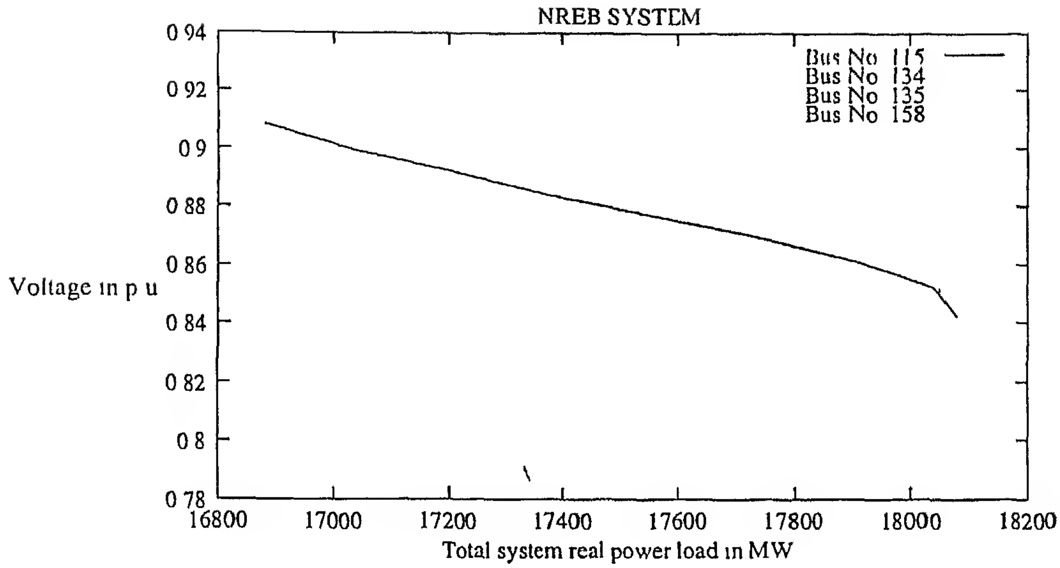


Figure 4 2 Voltages at buses 115 134 135 and 158 with system load increment modified to capture the stability limit

4 2 IEEE 30 Bus system

4 2 1 Load flow study

IEEE 30 bus system is a bench mark system generally used for power flow and stability studies There are other bench mark 4 bus system, 10 bus system, 75 bus system etc In this study 30 bus system is taken [7] Table 4 7 gives the base data about the number of buses, transformers, generators, etc of the IEEE 30 bus system

Load modelling is applied at nine buses where the loads are high The details of the buses and their real power at nominal values of voltages are given in Table 4 8

The reactive loss in the feeders at 1 0 p u voltage at the terminals of the load which form the input for reactive loss modelling are assumed to be as shown in Table 4 9

For the base case, LFP+LMP converged in four iterations The bus voltages and the

Table 4 7 Detalıs of IEEE 30 bus system

Number of buses	30
Number of transformers	4
Number of lınes	37
Number of load buses	24
Number of Generators	6
Slack bus number	1(Bus No 1)

Table 4 8 Buses modelled ın IEEE 30 bus system

BUS NUMBER	P_LOAD(MW)	Voltage(p u)
8	5 8	1 0
9	11 2	1 0
11	7 6	1 0
12	22 8	1 0
14	6 2	1 0
15	8 2	1 0
17	9 0	1 0
21	17 5	1 0
30	10 6	1 0

Table 4 9 Assumed initial reactive losses at the modelled buses

Bus no	Q_loss(MVAR)
8	0 1
9	0 35
11	0 15
12	1 2
14	0 2
15	0 3
17	0 7
21	0 3
30	0 5

corresponding real and reactive powers at the modelled buses are shown in Table 4 10 The loads at the modelled buses are as calculated by the LMP, in which the real and reactive losses and the compensation is also modelled

4 2 2 Static stability study

The load on the system was incremented by a factor of 1 1 at the end of each LFP+LMP convergence until the load flow failed Convergence was obtained for seven load increments When the system power level was incremented further, the load flow failed to converge The bus voltages and the corresponding real and reactive powers at the end of 7th load increment are given in Table 4 11

The variation of the voltage and the P and Q loads for different states of the system are stored in files specified by the user The voltages, P_{load} and Q_{load} of buses 12 and 21 at different system loadings are shown in Table 4 12

Table 4 10 Results at the end of LFP+LMP convergence

Bus No	Volt(p u)	P_load	Q_load
8	1 0346	6 0183	2 0755
9	1 0488	11 6264	6 0339
11	1 0233	7 7994	2 8406
12	1 0068	22 9119	12 6432
14	1 0329	6 4122	2 4237
15	1 0302	8 4535	3 3825
17	1 0298	9 1822	5 5035
21	1 0255	17 8055	9 5469
30	1 0378	10 8880	3 7957

Table 4 11 Results of the state prior to the failure of LFP

Bus No	Volt(p u)	P_load	Q_load
8	9029	12 5885	4 4050
9	9240	24 6422	11 4605
11	9543	17 0337	6 5130
12	9513	51 1413	29 1964
14	8881	12 9331	4 7384
15	8832	17 0513	6 6621
17	8880	19 5865	12 5561
21	8820	37 9393	16 2073
30	9047	21 5883	8 3055

Table 4 12 Voltage P_{load} and Q_{load} at buses 12 and 21 different system loadings

BUS 12					
A	B	C	D	E	F
1	139 697	44 445	1 007	22 912	12 643
2	154 700	49 615	1 004	25 493	14 117
3	171 572	55 434	1 000	28 432	15 811
4	190 176	61 610	994	31 768	17 740
5	211 352	68 712	990	35 657	20 042
6	234 702	76 180	981	40 089	22 655
7	260 660	84 083	968	45 190	25 663
8	289 735	92 636	951	51 141	29 196
BUS 21					
A	B	C	D	E	F
1	139 697	44 445	1 026	17 806	9 547
2	154 700	49 615	1 019	19 765	10 454
3	171 572	55 434	1 011	21 985	11 444
4	190 176	61 610	998	24 444	12 432
5	211 352	68 712	983	27 262	13 503
6	234 702	76 180	959	30 394	14 507
7	260 660	84 083	926	33 914	15 416
8	289 735	92 636	882	37 939	16 207

(This data is stored by LOADMOD in the file name specified by the user in file 'out_plot')

A	System state number(first one is the base case)
B	Total P_load of the system in MW
C	Total Q_load of the system in MW
D	Voltage at the bus in p u
E	P_load at the bus in MW
F	Q_load at the bus in MW

The voltage of buses 4, 8, 11 and 12 with increased loading of the system are shown in Figures 4 3 4 4 4 5 and 4 6 respectively Five conditions are taken to observe the system behaviour

- Load modelling applied at 9 buses
- Condition 1 + load mix change applied at bus 11 In this case the load mix change is applied at bus 11 in Models 6 and 28 Model 6 is commercial central air conditioner, which consumes more reactive power whereas Model-28 is water heater, which is a unity power factor load In each load increment the load of Model 6 is increased by 0 1 MW and the same is deducted from that of Model 28 Hence the voltage at this bus decrease as the total reactive power consumption is increasing This effect can be seen in Figure 4 5 for the bus 11 In this case the decrease in voltage is small but when loads of all models (load mix) change, keeping the real power constant, the reactive power of all the models put together (Q_{load} at the bus) changes causing change in the voltage at the bus
- Condition 1,2 + reactive power loss at the feeders taken into account and modelled
- Condition 1,2,3 + synchronous condenser at bus 4 removed after 3 load increments
- Condition 1,2,3,4 + load at bus 12 is removed after 3 load increments

Curves 1 to 5 in each of the Figures 4 3, 4 4 4 5 and 4 6 represent, respectively, the voltages of the buses 4, 8, 11 and 12 for the above mentioned conditions The load was incremented in small steps as the system reached the stability limit in order to capture the voltages properly

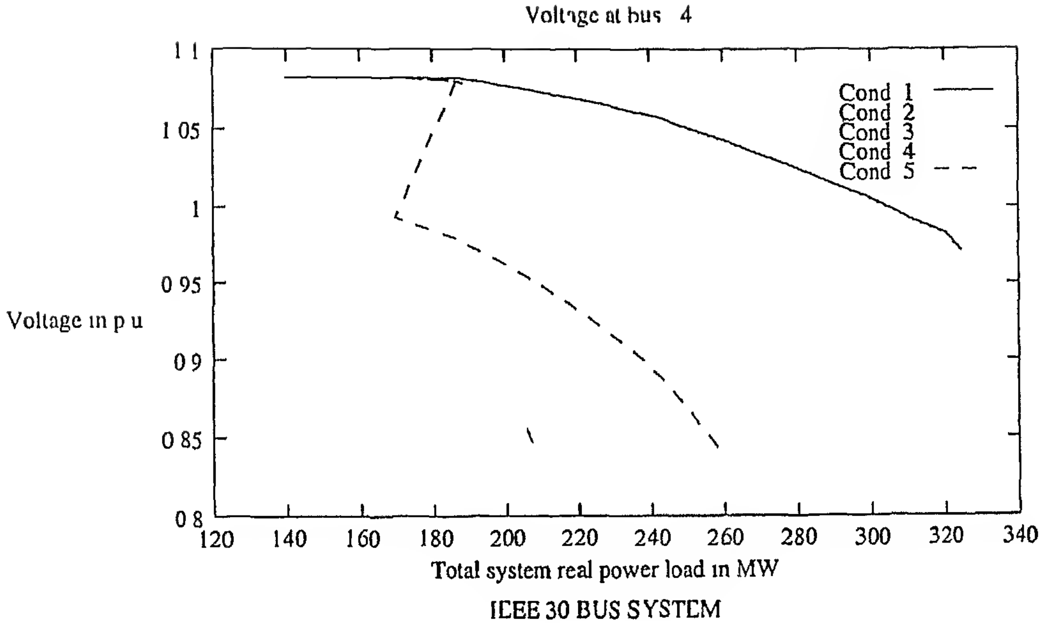


Figure 4 3 Voltage at bus 4 for different conditions of loading

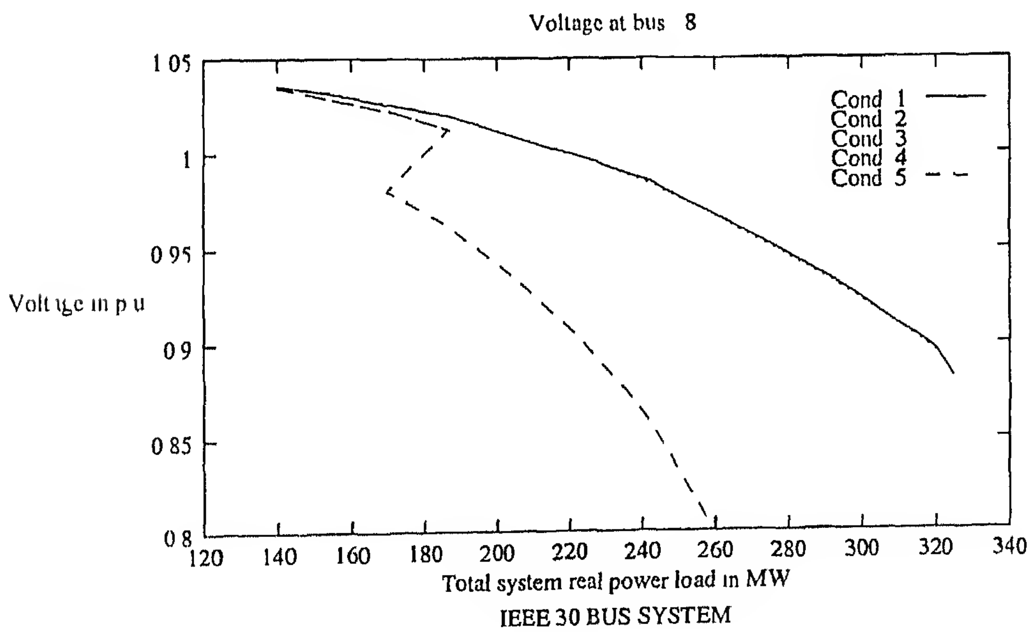


Figure 4 4 Voltage at bus 8 for different conditions of loading

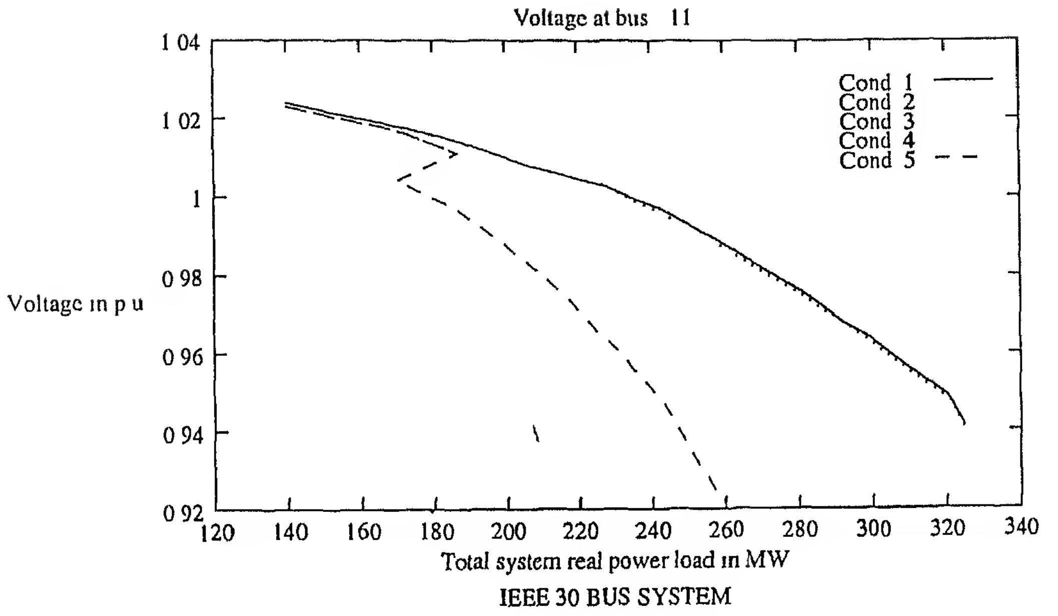


Figure 4 5 Voltages at bus 11 for different conditions of loading

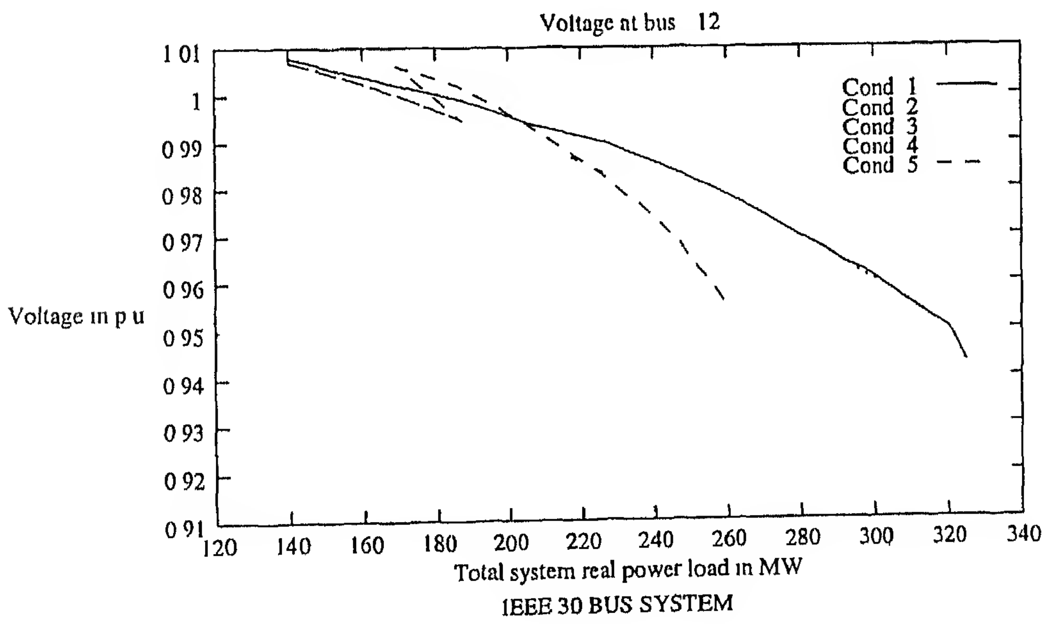


Figure 4 6 Voltages at bus 12 for different conditions of loading

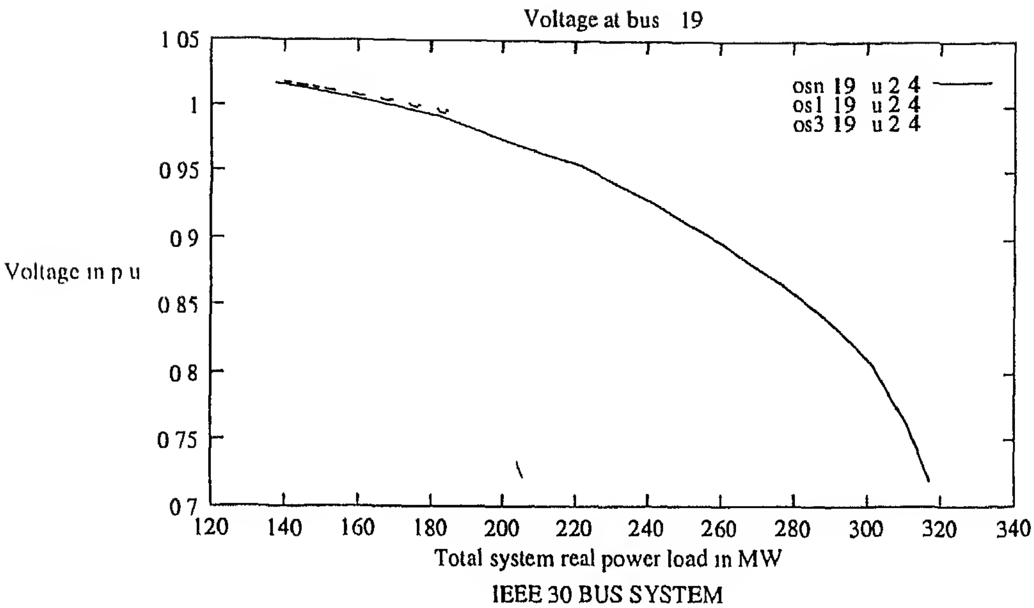


Figure 4 7 Voltages at bus 19 for different conditions of loading

With the load modelling applied at nine buses it was observed that the voltages at buses 18,19 and 20 decreased rapidly when the loading was increased To capture the voltages at these three buses accurately they were also modelled along with the nine buses The system loading was increased slowly to capture the static stability limit and it was observed that the voltage at bus 19 was least among all Figure 4 7 shows the voltage at the bus 19 for different loadings of the system Curve 1 shows the voltage at bus 19 without loads in the system modelled, and curve 2 is that with loads modelled at all 12 buses This shows that the actual system with load mix data as provided behaves as shown in curve 2 The voltage at bus 19 after considering the reactive losses and modelling them is as shown in curve 3 It is seen that the stability limit decreased

For the same loading at the bus, the reactive power calculated by the models for different load mix data is different because of which the modelled real and reactive losses also change This resulring reactive power causes the bus voltage to change when taken as input for the subsequent iteration of load flow Hence the load mix data is the main requirement for accuracy of final voltage levels With good load

statistics available when all load buses in the system are modelled, the results of load flow approach realistic values and the ststic stability limit can be captured properly

Chapter 5

Conclusions

- In the present work the characteristics of loads in the power system were considered for load flow and static stability studies The fixed compensation at the load bus was modelled for the changes in bus voltages Real and reactive losses in the feeders were modelled for the change in the loads for which the initial reactive power losses in the the feeders at 1 0 p u voltage at the terminal of the loads form the input

- The results of load flow with load modelling depend on the load mix data For proper performance, the data provided for the base case should be such that the real and reactive power outputs of all the models put together at 1 0 p u voltage plus the real and reactive power losses should be close to the specified P and Q at the bus If the load mix data is not proper then there is a mismatch between the calculated and specified values of reactive power under base load condition This results in improper voltage levels at the buses Hence accurate load mix data is the main requirement

Strengths

- Flexibility is provided for the user to study load flow with load modelling and

its application to static stability with different options for load modelling load increment iteration limits tolerance values for convergence of voltages generation of output files for each specified bus containing the information regarding the bus voltage real and reactive powers, etc

- The load modelling part of the program is developed in terms of different modules and can be linked with any load flow program easily

Limitations

- The buses where only Z load is present (only compensation) and are required to be modelled for fixed compensation need
  - to be represented in P Q load data with zero P load and Q load in MW instead in Z load data
  - the specification of zero P load for all the models in the load mix data

  Hence in a big system having many Z loads, the load composition data of all the models at all these buses is required to be fed

- The program is not supplied with any default load mix data

Scope for further work

- In the present work all load models are considered to be present at the bus and hence the votage input given to the models is the bus voltage However, voltage drops in the feeders may be modelled, and the resulting drops can be taken into into account for calculating the voltages at the models
- The dynamically behaving equipments may be modelled for their extended use in transient studies
- In countries like INDIA where the loads are high and voltage profile crosses the limits and collapses are frequent, load modelling with accurate load mix applied

at all load buses would help in accurately assessing the voltages and the margin of the stability limit this would require a survey to get the load mix and the load characteristics

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Appendix A

Computer code for Load Modelling Part of LOADMOD

```
C***********************************************************************
C                    LOAD MODELLING PART
C                           OF
C                      L O A D M O D
C***********************************************************************

c        ********************
c              MODULE 1
c        ********************

c  VARIABLES USED IN    LMP
       real bpwr(1000) v01(1000) f0 v f dt v0 qq(1000) p q
       real p1 q1 p2 q2 v2
       real fact load(50) fact l xx1(1000) xx2(1000) xx3
       real ppload ppgen pplosses qqgen qqload qql sses abs1 abs2 abs3
       real lm chang (1000 500) lm chan abs4
       integer bn(1000) tnb nnnn ij i2 nall load itr nbl1 ii2
       integer i6 bnlic(500) load r q load itrn(50) tmp1 tmp2
       integer load mix y load mix itr lm buses lm models
       integer lm busno(1000) lm mod no(500) lm mark1 lm mark2
       integer r pause
       character*20 lm char
       integer req out file req all of out unit
       integer out nobus out itr out busno(1000)
       character*6 o f
       character*2 o f1
       integer req gen out no gen out gen out(1000)
       integer gen out itr(1000) i8 j8
       real gen out fact(1000) flag123
       integer req ld out no_ld out ld out(1000)
       integer ld out itr(1000) ldobus(1000) mark3
       real ld out fact(1000) ldofac(1000) ld outage p11
       real l2 l1i l12 rec buses rec bus(500) rec loss(500)
       integer req rec loss ii4 flagi lfp lmp lfplmp itr(10) req vtol
       integer limit var lim flag
       real v limit v lim temp(10) v limit1
       complex s1(500) s2(500)
c  FILES USED IN  - LMP   -                                      -
        open(unit 50550 file  itr out1 )
             open(unit=8989 file= itr out2 )
       open(unit 6789 file= out plot')
       open(unit 6788 file= out file names )
```

```
       p n(unit 7000 file  gen  utag  )
      op n(unit 7001 fil   load outag  )
      op n(unit 5010 file  itr limit )
*

c  FILE  lfdata  CONTAINS THE INPUT DATA FOR   LFP
c  FILE  nr out  IS THE OUT PUT OF   LFP   WHERE THE BUS VOLTAGES
c              P & Q ARE PRINTED  AT THE END OF EACH LOAD FLOW RUN
c  FILE  data out  IS THE OUT PUT OF   LFP   WHICH GIVES THE INPUT
               AND OUT PUT DETAILS
c

c        ***************** ***
c              MODULE 2
         ********************

c
c   qq  IS A REAL ARRAY IN WHICH THE COMPENSATION AT THE LOAD BUS IS STORED
c  WHICH IS USED FOR ITS MODELLING IN   LMP   AND THEN SUBTRACTED FROM THE Q load
      qq(i) x3


c        ********  ***********
c              MODULE 3
c        *********************

c      READING DATA FOR LIMITS IN ITERATIONS OF LFP  LFP+LMP CONVERGENCE AND
       VOLTAGE TOLERENCE FOR CONVERGENCE OF LFP+LMP FROM FILE   tr limit
        read(5010 *)
        read(5010 *)lfp
        read(5010 *)
        read(5010 *)lmp
        read(5010 *)
        read(5010 *)v limit
        v limit1 v limit
        read(5010 *)
        read(5010 *)req vtol
        read(5010 *)
        read(5010 *)limit var
        read(5010 *)
        do 5011 i=1 limit var
         read(5010 *)lfplmp itr(i) v lim temp(i)
5011       continue
        lim flag 1

c      READING DATA FOR GENERATOR OUTAGES DURING LOAD INCREMENTS AT THE
c      END OF LFP+LMP CONVERGED RUN FROM FILE  gen outages
        read(7000 *)
        read(7000 *)req gen out

        if(req gen out eq 1)then
         read(7000 *)
          read(7000 *)no gen out
          read(7000 *)
         do 7200 i=1 no gen out
          read(7000 *)out itr gen out(i) gen out itr(i) gen out f ct(i)
7200        continue
        else
         close(7000)
        endif

c      READING DATA FOR LOAD OUTAGES DURING LOAD INCREMENTS AT THE
c      END OF LFP+LMP CONVERGED RUN FROM FILE  1 ad outages
        read(7001 *)
        read(7001 *)req ld out

        if(req ld out eq 1)then
         read(7001 *)
```

```
         read(7001 *)no ld out
         r ad(7001 *)
        do 7100 ı 1 n  ld o t
         read(7001 *)out ıtr ld  ut(ı) ld  ut ıtr(ı) ld out fact(ı)
7100        contınu
        ls
        no ld out 0
        clos (7001)
        ndif
c       VARIABLE  mark3  IS THE FLAG FOR NOTING THE LOAD OUTAGE
        DURING THE RUN TIME ITS VALUE CHANGES TO 1 WHEN THERE IS AN
c       OUTAGE OR ELSE IT REMAINS 0
         mark3 0

        READING DATA FOR GENERATION OF OUT PUT FILES FOR V  P  Q AT BUSES
c       FOR TOTAL REAL & REACTIVE POWERS OF THE SYSTEM THROUGHOUT THE LOAD
c       INCREMENT ITERATIONS ( LFP+LMP CONVERGED ) FROM FILE  out plot

c       THIS USES ANOTHER FILE   ut fıl  name   TO CREATE & STORE THE DEFAULT
        FILE NAMES (  o BusNo   ) WHEN THE ABOVE OPTION IS CHOOSEN

         read(6789 *)
         read(8789 *)
         read(8789 *)req  ut fıl

         ıf(r q out file eq 1)then
           r ad(6789 *)
           read(8789 *)req all of

          ıf(req all of eq 1)then
            o f1  o
           do 855 ı 1 nbus
           if(i lt 10)then
            write(6788 858)o f1 ı
656         format(a2 i1)
           endıf
           if((ı ge 10) and (i lt 100))then
            write(6788 658)o f1 ı
858         format(a2 ı2)
           endıf
           ıf((ı ge 100) and (i lt 1000))then
            write(8788 859)o f1 ı
659         format(a2 i3)
           endıf
855           continue
           close(6788)
           open(unit 6788 file  out file names )
           out unit 8000
         do 857 i 1 nbus
           out unit out unit+1
           read(8788 *)o f
           open(unit out unit file o f)
857         continue

          else

           read(8789 *)
           read(6789 *)out nobus
           read(6789 *)
         do 670 i 1 out nobus
           out unit 6000
           read(6789 *)out itr out busno(i) o f
           out unit out unit+out busno(i)
           open(unit=out unit file o f)
670         continue

          endif
```

```
        ndif

       WRITING THE OUT PUT DETAILS IN THE FILE  itr  ut2
        writ  (8989 *)( ITN   BUS NO    VOLTAGE        P          Q )
        writ  (8989 *)(                   (KV)        (MW)      (MVAR) )
        wr te(8989 *)
        writ  (8989  )
        writ  (8989 *)( *********** LOADMOD ITR   1   ***  ***   * )
        writ  (8989 *)
        writ  (8989 *)

c      READING THE OPTION FOR THE CHANGE IN THE LOAD MIX OF THE LOAD AT THE
c      BUS FROM FILE  1 ad mix change
        p n(unit 9000 file  lo d mix  hange )
        read(9000 *)
        r ad(9000 *)load mi  y

        if(l ad mix y eq 1)th n
         read(9000 *)
         read(9000 *)l ad mix itr
        else
         close(9000)
        endif

       READING DATA FOR REACTIVE POWER LOSS IN THE FEEDERS AT THE LOAD
c      BUSES FOR ITS MODELLING FROM FILE  react l s
        open(unit 321 file  react l  s )
        read(321 *)
        read(321 *)req rec loss

        if(req rec loss eq 1)then
          r ad(321  )
          read(321 *)rec buses
          r ad(321 *)
         do 322 i 1 rec buses
          read(321 *)rec bus(i) rec l  s(i)
322        continu
        else
          close(321)
        endif

c      THE LOAD AT A BUS IS DIVIDED AMONG THE DEFINED LOAD MODELS
c      + IOSSES  THE E DETAILS OF ALL BUSES IS IN FILE  load composition
        open(unit 31 file  load composition )
        nnnn 31

c      THE FILE  load modelling  IS THE MAIN OPTION FOR LOAD MODELLING
c      WHICH ACTIVATES    LMP  -   THE DATA FOR CHOICE OF BUSES AND
c      THEIR REAL POWER LOADS ARE READ FROM THIS FILE AND  LMP  IS
c      ACTIVATED TO GET THE REAL AND REACTIVE POWER AT THESE BUSES
c      WHICH ARE STORED IN ARRAY  s1    THESE ARE USED FOR MODELLING
c      REAL AND REACTIVE POWER LOSS IN THE FEEDERS AT THE LOAD BUSES
        open(unit 5 file  load modelling )
        read(5 *)
        r ad(5 *)tnb
        read(5 *)
        read(5 *)f0 f dt
        read(5 *)

        if(tnb eq 0)then
          rewind(5)
        else
         do 7991 i 1 tnb
          read(5 *)bn(i) bpwr(i) v01(i)
          v=1 0
          f 50 0
          dt 0 0
          v0 v
```

```
         f0 f
         ıȷ bn(ı)
         p 0 0
         q 0 0
         f ct l 1 0
         lm mark2 0
         lm mod l  i
         lm mod no 1
         lm change 0 0
         m rk3 0
         ld outage 1 0
         s1(ıȷ) (0 0 0 0)
         flag1 1
       call model(v f dt v0 f0 nnnn ı ıȷ p q fa t l lm mark2
     *          lm m d ls lm mod no lm  hang  mark3 ld  utag   1 fl gi p11)
          1(ıȷ) cmplx(p11 q)
7991        c ntınue
        cl s (5)
       endıf

       close(nnnn)

       fact l 1 0
       flag1 0

c      WHEN LFP+LMP CONVERGES AND LOAD IS INCREMENTED FOR NEXT STATE
c      OF THE SYSTEM IT RUNS FROM THE STATEMENT LABELLED  8980
c      VARIABLE  ı6  KEEPS TRACK OF THE ITERATION NUMBER

c      WHEN ONE LFP+LMP RUN IS OVER IT IS REPEATED FOR NEXT RUN FROM
c      STATEMENT LABELLED  899   VARIABLE  ı2  KEEPS TRACK OF THE
c      ITERATION NUMBER
       i6 0
8980      i2 0
       i6 i6+1
899       i2 ı2+1
       wrıte(8989 *)(     (LFP + LMP) ITR      ı2              )


c         ********************
c               MODULE 4
c         ********************

c      THE FILE WITH UNIT NUMBER  2  ( nr out ) IS CLOSED AT THE END
c      OF EACH LOAD FLOW RUN
       close(2)

c      THE DETAILS OF THE BUSES TO BE MODELLED ARE READ FROM  l  d modellıng
c      AND LOAD COMPOSITION FROM  load composition
       open(unit 5 file  load mod lling )
       read(5 *)
       read(5 *)tnb
       read(5 *)
       read(5 *)f0 f dt
       read(5 *)

c         ++++++++++++++++
       if(tnb eq 0)then
       rewind(5)
       else

       do 799 i 1 tnb
       read(5 *)bn(i) bpwr(ı) v01(i)
799       continue

       close(5)

       open(unit=31 fıl   load_c mposition )
```

```
         f0 f
         ıȷ bn(ı)
         p 0 0
         q 0 0
         fact 1 1 0
         lm ma k2 0
         lm mod l  1
         lm m d n  1
         lm chang  0 0
         mark3 0
         ld  utag  1 0
         s1(ıȷ) (0 0 0 0)
         fl g1 1
        call model(v f dt v0 f0 nnnn ı ıȷ p q f ct l lm mark2
     *        lm m d ls lm mod n  lm chang  mark3 ld out g   1 fl g1 p11)
         s1(ıȷ)  mplx(p11 q)
7991        contınu
         close(5)
        endıf

        close(nnnn)

        fact 1 1 0
        flag1 0

c      WHEN LFP+LMP CONVERGES AND LOAD IS INCREMENTED FOR NEXT STATE
c      OF THE SYSTEM IT RUNS FROM THE STATEMENT LABELLED  8980
c      VARIABLE  ı6  KEEPS TRACK OF THE ITERATION NUMBER

c      WHEN ONE LFP+LMP RUN IS OVER IT IS REPEATED FOR NEXT RUN FROM
c      STATEMENT LABELLED  899   VARIABLE  ı2  KEEPS TRACK OF THE
c      ITERATION NUMBER
        ı6 0
8980       i2=0
        i6 i6+1
899       i2 i2+1
        write(8989 *)(    (LFP + LMP) ITR     ı2              )


c        *********************
c              MODULE 4
c        *********************

c      THE FILE WITH UNIT NUMBER  2  ( nr out ) IS CLOSED AT THE END
c      OF EACH LOAD FLOW RUN
        close(2)

c      THE DETAILS OF THE BUSES TO BE MODELLED ARE READ FROM  l  d m d llıng
c      AND LOAD COMPOSITION FROM  load composition
        open(unit 5 file  load mod llıng )
        read(5 *)
        read(5 *)tnb
        read(5 *)
        r ad(5 *)f0 f dt
        read(5 *)

c        ++++++++++++++++
        if(tnb eq 0)then
        rewind(5)
        else

        do 799 i 1 tnb
        read(5 *)bn(i) bpwr(i) v01(i)
799        continue

        close(5)

        open(unit 31 file  load_composition )
```

```
      nnnn 31

      p1 0 0
      p2 0 0
      q1 0 0
      q2 0 0

c     READING THE DATA FOR THE CHANGE IN THE LOAD MIX OF THE LOAD AT THE
      BUS FROM FILE  1 ad mix change
       if(i2 eq i)th n
        if(load mix y eq i)then
          r ad(9000 *)
          r ad(9000 *)
          r ad(9000 *)lm char lm buses
          r ad(9000 *)
         do 459 i i lm buses
          read(9000 *)lm char lm busno(i)
          r ad(9000 *)lm char lm m d ls
         do 458 j i lm mod ls
          read(9000 *)lm char lm mod no(j) lm  har lm chan
          tmpi lm busno(i)
          tmp2 lm mod no(j)
          lm chang (tmpi tmp2) lm chang (tmpi tmp2)+lm  han
458         continue
459         continue
        endif
       endif

       lm marki i

c     EACH BUS TO BE MODELLED IS TAKEN ONE 8Y ONE
c     BY TAKING INTO ACCOUNT ALL THE OPTIONS
       do 798 i i tnb

       if((load mix y eq i) and (lm busno(lm marki) eq bn(i)))then
c     VARIABLE  lm mark2  IS THE FLAG FOR CHANGES IN LOAD MIX ITS
c     VALUE IS MADE i IF LOAD MIX IS PRESENT OR ELSE REMAINS 0
        lm m rk2 i
         if(lm marki lt lm buses)then
          lm marki lm marki+i
         endif
       else
        lm mark2 0
       endif

       v0 v01(i)
       ij bn(i)

c     TRANSFERING THE VOLAGE AT BUS  ij  OBTAIND FORM LOAD FLOW PART IN
c     VARIABLE  x  TO VARIABLE  v  TO BE USED IN LOAD MODELLING PART
       v x(nbus+ij)

       mark3 0
       if(req ld out eq i)then
        do 7030 i8 i no ld out
         if((i6 i) ge ld out itr(i8))then
           j8 ld out(i8)
          if(j8 eq ij)then
           ld outage ld out fact(i8)
           mark3 i
           pload(j8) pload(j8)*ld outage
           qload(j8) qload(j8)*ld outage
           go to 7031
          else
           mark3 0
           ld outage i 0
          endif
         else
```

```
        mark3 0
        ld outag  1 0
        ndif
7030         ntinu
      else
       mark3 0
       ld out g  1 0
      endif
7031       flagi23-0 0

        2 v
      v v*v0

c     FOR EACH BUS SUBROUTINE  mod l  IS CALLED WHICH CALCULATES
c     FINAL P & Q OF THE LOADS AT THE BUS
       call model(v f dt v0 f0 nnnn i ij p q fact l lm mark2
     *         lm models lm m d no lm  hange mark3 ld outage si flagi pli)

       if(mark3  q 1)then
       qq(ij) 0 0
       endif

      PUTTING BACK CHANGED REAL & REACTIVE POWERS AT THE BUS OBTAINED AFTER
c     APPLYING THE LOAD MODELLING FOR CHANGED VOLTAGE INTO THE VARIABLES
c      pl ad  &  ql ad  WHICH ARE USED BY LOADFLOW PART
       pload(ij) p

c     MODELLING THE COMPENSATION
       qq(ij) qq(ij)*v2*v2

       qload(ij) q qq(ij)

      MODELLING THE REACTIVE POWER LOSS IN THE FEEDER AT THE BUS
       if(bpwr(i) gt 0 00001)then
       if(req rec loss eq 1)then
        do 324 ii2 1 rec buses
         if((rec bus(ii2) eq ij) and (mark3  q 0))then
          s2(ij)  mplx(pli q)
          ll2=cabs(s2(ij))/cabs(si(ij))
          lli r c lo s(ii2)/(v2*v2)
          l2 lli*ll2*ll2
          qload(ij)=qload(ij)+l2
         endif
324       continue
       endif
       endif

       mark3 0

c     WRITING THE MODELLED BUS VOLTAGE  P & Q IN OUTPUT FILE  itr out2
       write(8989 891)i2 bn(i) v pload(ij) qload(ij)
891       format(1x i3 3x i3 7x f8 4 3x f9 4 3x f9 4)

c     VARIABLES  pinj  &  qinj  ARE INJECTIONS OF REAL & REACTIVE POWERS
c     AT THE BUS USED IN THE LOAD FLOW PART
       pinj(ij)  pload(ij)/base
       qinj(ij)  qload(ij)/base

798       continue

       close(nnnn)
       close(nin)

c     STORING PERSENT VOLTAGES IN ARRAY  xxi  FOR VOLTAGE TOLERENCE
c     COMPARISION IN THE NEXT ITERATION
       if(i2 eq 1)then
        do 5050 i=1 nbus
         xxi(i)=x(nbus+i)
```

```
5050      c ntinu
      endif

     STORING THE MAXIMUM VALUE DIFFERENCE IN THE VOLTAGE IN VARIABLE  xx3
      xx3 0 0
      if(i2 ge 2)then
       d  5051 i 1 nbu
         xx2(i) ab ( xx1(i)   x(nbu +i) )
        if(xx2(i) gt xx3)th n
         xx3 xx2(i)
        endif
5051      c ntinu

       do 5052 i 1 nbus
        xx1(i) x(nbus+i)
5052      continue
      endif

c     SETTING THE VOLTAGE TOLFRENCE LIMIT IF IT CHANGES
      if(req vtol eq 1)then
      if(i2 eq lfplmp itr(lim flag))th n
      v limit v lim t mp(lim flag)
      lim fl g lim flag+1
      endif
      endif

      if(i2 gt lmp)then
       write(* *)( COULD NOT CONVERGE IN   lmp   ITERATIONS OF
     *       LOADMODEL PROGEAM )
       stop
      endif
      write(* *)(    END OF LOAD MODEL & LOAD FLOW ITR    i2)
      write(* *)
      write(* *)( VOLTAGE DIFFERENCE IN ITERATIONS IN P U     xx3)
      write(* *)( VOLTAGE LIMIT TOLERENCE IN P U             v limit)
      write(* *)
      if((xx3 ge v limit) or (i2 eq 1))then
       go to 899
      else
       write(* *)(                                              )
       write(* *)(             L F P   +   L M P      CONVERGED )
       write(* *)(                                              )
      endif

      endif
c      +++++++++++++++++

      lim flag 1
      v limit v limiti

      write(8989 *)
      write(8989 *)( ********** LODMOD  ITR     i6+1  ************ )
      write(8989 *)


c     WRITING THE VOLTAGES  REAL AND REACTIVE POWER INJECTIONS AT ALL BUSES
c     IN THE OUT PUT FILE  itr out1   THIS IS WRITTEN AFTER
c     THE CONVERGENCE OF LFP+LMP
       ppgen 0 0
       ppload 0 0
       qqgen 0 0
       qqload 0 0
       pplosses 0 0
       qqloss s 0 0

       do 50551 i 1 nbus
        if(iflag(i) eq 1)then
         ppload ppload+pinj(i)
```

```
        qqload qqlo1d+q1nj(1)
        ls
        ppg n ppg 1+p1nj(1)
        qqgen qqgen+qinj(i)
       end1f
       pplosses ppg n+ppload
       qqloss   qqg n+qqlo d
50551      cont1nue

      WRITING INTO OUT PUT FILE  1tr out1
       write(50550 *)(         ITR No    16                        )
       wr1t (50550 *)( Bas  MVA      ba e     Pg n     ppgen)
       wr te(50550 *)( Pload      ppload    Los  s     ppl       )
       wr1t (50550 *)( Bus No      V      P1nj       Ql ad )
       wr1te(50550 *)(           (p u)    (p u)      (p u) )

       d  5055 1 i nbus
        wr1te(50550 50552)i x(nbus+1) p1nj(1) q1nj(1)
5055      cont1nue
50552      format(i3 2x 3(f9 4 2x))


c     WRITING THE VOLTAGES  AND P & Q INJECTIONS AT THE BUSES IN SEPERATE
c     FILES AS PER THE REQUIREMENTS SPECIFIED IN DATA FILE   ut pl t
       1f(req out f1le eq 1)then
        1f(req all of eq 1)th n
          out un1t 6000
         do 681 i 1 nbus
          out unit out unit+1
          abs1 abs(ppload)*base
          abs2 abs(pinj(i))*base
          abs3 abs(qinj(1))*base
          abs4 abs(qqload)*base
          write(out unit 682)i6 abs1 abs4 x(nbu +1) abs2 abs3
681          continue
682           format(i3 5(3x f9 3))
        else
         do 683 i 1  ut n bus
          out un1t 6000
          out unit out unit+out bu no(i)
          j out busno(i)
          abs1 abs(ppload)*base
          abs2 abs(p1nj(j))*base
          abs3 abs(qinj(j))*base
          abs4 abs(qqload)*base
          write(out unit 684)i6 abs1 abs4 x(nbu +j) abs2 abs3
683          continue
684           format(i3 5(3x f9 3))
         ndif
       endif

c     GENERATOR OUTAGES
       if(req gen out eq 1)then
       do 7010 i 1 no gen out
       if(i6 ge gen out itr(i))then
       j=gen out(i)
       pgen(j) pgen(j)*gen out fact(i)
       qmax(j) qmax(j)*gen out_fact(i)
       qmin(j) qmin(j)*gen out fact(i)
c     WHEN GENERATORS ARE OUT THEY ARE TREATED AS LOAD BUSES
c     FROM THE NEXT ITERATION BY MAKING  IFLAG(BUS)  ZERO
c     IFLAG IS A VARIABLE IN  LFP  WHICH IS
c      1  FOR LOAD BUSES
c      2  FOR GENERATOR BUSES
c      3  FOR SLACK BUS
       iflag(j) 1
c
       end1f
```

```
7010      continue
      end f

c     LOAD OUTAGES
      if(req ld out oq 1)then
      do 7020 i i no ld out
      if(i6 ge ld out itr(i))then
      j ld out(i)
      pload(j) pl  d(j)*ld out fact(i)
      ql ad(j) qload(j)*ld out fact(i)
      ld bus(i) j
      ld fa (i) ld out fa t(i)
      mark3 1
       ndif
7020        nt nu
      endif

c     READING THE DATA FOR LOAD INCREMENT FROM FILE  1  d in rem nt
      if(i6  q i)then
         open(unit 505 file  load incr ment )
         road(505 *)
         read(505 *)load req
        if(load req eq 0)then
         stop
        endif
       r ad(505 *)
       read(505 *)load itr
       read(505 *)
       read(505 *)r pau
       read(505 *)
       do 509 i i load itr
        read(505 *)load itrn(i) fa t l ad(i)
509       continue
       read(505 *)
       read(505 *)nall
       read(505 *)
       r ad(505 *)nbli
       read(505 *)
       do 508 i i nbli
        read(505 *)bnlic(i)
508       continue
      endif

c     MULTIPLYING THE LOAD FACTOR WITH THE NEW AMMOUNT OF INCREMENT
      fact l fact l*fact load(i6)

c     INCRFASING THE GENERATION AND LOAD
      if(nall  q i)then
       do 506 i 1 nbus
        pgen(i) pgen(i)*fact load(i6)
        pload(i)=pload(i)*fact load(i6)
        qload(i) qload(i)*fact load(i6)
c        qmax(i) qmax(i)*fact load(i6)
c        qmin(i) qmin(i)*f ct_load(i6)
         if(req rec loss eq 1)then
          do 325 ii4 1 rec buses
           if(rec bus(ii4) eq i)then
            rec loss(ii4) rec loss(ii4)*fact load(i6)
           endif
325          continue
         endif
506        continue
       else
        do 507 i=1  nbli
         j=bnlic(i)
         pgen(j)=pgen(j)*fact load(i6)
         pload(j)=pload(j)*fact load(i6)
         qload(j) qload(j)*fact load(i6)
```

```
         qm x(j) qm x(j)*fact load(i6)
c        qmin(j) qmin(j)*fact lo d(i6)
507       continue
       ndif

      if(i6 lt 1 ad itr)then
       write(* *)
       write(*  )(       ******************** ***** ** )
       write(* *)(       *                            * )
       write(* *)(               END OF LOAD INC  ITR     i6)
       write(* *)(       *                            * )
       write(* *)(       * *************************** )
       if(r paus   q 1)then
        pause
       endif
       go to 8980
      endif

      write(  *)(       ***************************** )
      write(* *)(       *                           * )
      write(* *)(               END OF LOAD INC  ITR     i6)
      write(* *)(       *                           * )
      write(* *)(       ***************************** )

      if(r pause eq 1)then
       pause
      endif
      close(505)


C*** ************** ****** ********************************************* **
c        SUBROUTINE FOR READING THE MODEL LOADS
c       IMPLEMENTING INCREMENTS  OUTAGES AND MODELLING THE REAL LOSSES
C**************** *********************************************************

      subroutine model(v f dt v0 f0 nnnn iji ijij p q fact l
     *        lm mark2 lm models lm mod no lm chang  mark3 ld  utage
     *        si flagi pli)

      implicit none

      integer no model iji ijij lmm3 lmlm mark3 flagi
      integer i nn nnnn lm mark2 lm models lm mod no(500)
      real realp(1000) reactp(1000) lm change(1000 500)
      real v v0 f f0 dt add change ll3 ll4
      real p q cat loss ml(1000) fact l ld outage v21 pli
      character*20 area ci c2
      complex si(500) s3(500)

c
c      open(unit=30 file= program dat )
c      open(unit 32 file  program data )
      open(unit=44 file= program1 out4 )
      open(unit 45 file  program1 out5 )
      open(unit=22 file= comp code )
c
c  no model   gives the total numer of models used

      cat loss 0 0

c     READING INFORMATION REGARDING NUMBER OF MODELS FROM FILE  comp code
       read(22 *)
       read(22 *)
       read(22 *)no_model
       rewind(22)

c     READING THE NAME OF THE AREA FROM FILE  load composition
       read(nnnn *)
```

```
       r ad(nnnn 13)aroa
13       format(t38 a20)
       read(nnnn *)

       lmm3 1
       do 1011 i 1 no model
      READING THE MODEL LOAD INTO THE VARIABLE  ml
       read(nnnn *)nn ml(i)

c     NOTING LOAD MIX CHANGES
       if((lm mark2 eq 1) and (lm mod no(lmm3)  q i))th n
       lmlm lm mod no(lmm3)
         add chang  lm chang (ijij lmlm)
         if(lmm3 lt lm models)then
          lmm3 lmm3+1
          ndif
       else
        add change 0 0
        ndif

c     IMPLEMENTING MODEL LOAD INCREMENT IN LFP+LMP CONVERGED ITERATION
c     LOAD MIX CHANGE AND LOAD OUTAGES
       ml(i) ml(i)*fact 1
       ml(i) ml(i)+add change
       ml(i) ml(i)*ld outage

1011        continue

c     READING THE LOSS AND ITS MODEFICATION FOR LOAD OUTAGE
       read(nnnn *)c1 cat loss c2
       if(mark3 eq 1)th n
       cat loss cat loss*ld outage
       endif

       if(iji eq 1)then
       if(flagi eq 0)then
       write(45 *)( THE VARIATION IN P & Q WITH VOLTAGE & FREQUENCY IN )
168       format(20x 20a)
       write(45 *)( BUS TIME    VOLT   FREQ       P        Q       AREA )
       endif
       endif


c     THE MODEL LOAD INFORMATION   PRESENT VOLTAGE  FREQUENCY  TIME STEP
c     ARE TRANSFERED TO SUBROUTIN  modelchar   WHICH IMPLEMENTS EACH MODEL
c     CHARACTERISTICS   THE REAL AND REACTIVE POWERS OF ALL MODELS AFTER
c     THE CHARACTERISTICS APPLIED ARE STORED IN REAL ARRAYS  r alp
c     AND  reactp
       call modelchar(v v0 f f0 realp reactp dt ml)

       if(flagi eq 0)then
c       write(44 *)( THE LOADS OF MODELS WITH CHARACERISTICS )
c       write(44 169)area
c169       format(2x  AREA     5x 20a)
c       write(44 *)( Voltage      v    Frequ ncy     f)
c       write(44 *)
c       write(44 *)(  MODEL NUMBER    REAL POWER     REACTIVE POWER )
c       write(44 *)(  fact 1      fact 1)
c       write(44 *)(                       ( in MW )        ( in MW ) )
c       write(44 *)
       endif

       p 0 0
       q 0 0

c     ADDING ALL THE MODELLED REAL AND REACTIVE POWER OUT PUTS INTO
c     VARIABLES  p  and 'q
       do 172 i 1 no model
```

```
        if(fl gi eq 0)th n
c         writ (44 93)i r alp(i) r actp(i)
        endif
        p p+realp(i)
        q q+r actp(i)
172       continue

      pii p
93      format(5x i3 t15 fii 4 t31 fii 4)

c     MODELLING THE LOSSES AT THE FEEDERS
      if(p gt 0 00001)th n
      if(flagi eq 0)then
      v21 v/v0
      s3(ijij) cmplx(p q)
      ll4 cabs(s3(ijij))/cabs( i(ijij))
      ll3 cat l s /(v21* 21)
      c t loss ll4*ll4*ll3
       l e
      cat loss 0 0
      endif
      endif

      if(flagi  q 0)then
c      writ (44 *)
c      write(44 99)cat loss
99      f rmat(2x  LOS ES   3x f10 4   MW )
      endif

c     LOSSES BEING ADDED TO TOTAL LOAD OBTAINED AT THE BUS
      p p+cat loss

      if(flagi eq 0)then
c      write(44  )
c      write(44 *)( TOTAL REAL POWER     p   MW   REACTIVE POWER
c     *        q   MW )
c      write(44 *)
c      write(44 *)(      *************************  *    )
c      write(44 *)
      endif

      if(flagi eq 0)then
      write(45 166)ijij v f p q area
166      format(i3 1x f9 3 1x f6 3 1x f9 4 1x f9 4 1x a10)
      endif

      return
      end
c*************** ******************************************************* *
c           SUBROUTINE FOR
c              IMPLEMENTING THE MODEL CHARACTERISTICS
c*************************************************************************

      subroutine modelchar(v v0 f f0 realp rea tp dt ml)

      implicit none

      integer s d i ii
      integer nmodel model no nom nnn flag nfile
      real theta realp(1000) reactp(1000)
      real p q p0 q0 v v0 f f0 dt v2 ml(1000)
      real model load modn nr rm nmm dp dq
      real pof pv pf qv qf nm pofnm pvnm pfnm qvnm qfnm
      character*1 e p exp pol
      character*6 model code m c

      open(unit 41 file  s d )
      open(unit 42 file  comp char )
```

```
      p n(unit 49 filo  comp  harp )
     open(unit 51 filo  d d )
     nfile 51

     r ad(41 *)
     r  d(41 *)
     read(41 *)nm del
     road(41 *)
     r ad(41 *)

     road(42 *)
     read(42 *)
     read(42 *)
     r ad(42 *)
     read(42 *)

      rm 0 0

     EACH MODEL  IS TAKEN ANO THE OPTIONS FOR THE TYPE OF CHARACTERISTICS
c    EXPONFNTIAL OR POLAR IS READ FROM FILE  s d

      do 171 i i nmodel
        read(41 *)model no s d e p
      model load ml(i)
      flag 0
c   * * ** * *** ********
      if(s gt 0)then
          flag i
          exp  e
          pol  p
        if(e p eq exp)then

      READING THE PARAMETERS OF THE LOAD MODEL FOR EXPONENTIAL MODEL
c     FROM FILE  comp char
        read(42 *)nom model code pof pv pf qv qf nm
    *          pofnm pvnm pfnm qvnm qfnm

          if(nom eq i)then
           read(49 *)
          else
           write(* *)( reading from the files is wrong )
          endif
c     OBTAINING THE INITIAL Qo OF THE MODEL FROM IT S POWER FACTOR
          p 0 0
          q 0 0
          p0 model load*(s*0 01)
          theta acos(pof)
          q0 p0*tan(theta)

c     IMPLEMENTING MODEL CHARACTERISTICS
          if((nm eq 0 0) or (nm eq 1 0))then
c        For Nm 0 0 or Nm 1 0
c              -
        p p0*((v/v0)**pv)*((f/f0)**pf)
        q q0*((v/v0)**qv)*((f/f0)**qf)
          elseif((nm gt 0 0) and (nm lt 1 0))th n
c        For Nm between 0 and 1
c
               p = nm*p0*((v/v0)**pv)*((f/f0)**pf) +
    *         (1 nm)*p0*((v/v0)**pvnm)*((f/f0)**pfnm)
        q = nm*q0*((v/v0)**qv)*((f/f0)**qf) +
    *         (1 nm)*q0*((v/v0)**qvnm)*((f/f0)**qfnm)
          endif

          realp(i)=p
          reactp(i) q

         elseif(e p eq pol)then
```

```
c
          read(49 *)n m        and th  oth r things
c         if(nom eq i)then
c          read(42 *)
c         el e
           writ (* *)( reading from the file  i  wr ng )
           ndif

c  THE POLYNOMIAL PART CAN BE ADDED HERE

        endif
c
      endif
c    *****    ************
c           =      =
      if(d gt 0)then
c             THE DYNAMIC PART CAN BE ADDED HERE
       if(flag eq 0)then
        read(42 *)
        read(49 *)
       endif

      p 0 0
      q 0 0
c READING DATA FOR DYNAMIC MODELLING OF INDUCTION MOTOR FROM FILE  d d
      read(51 *)
      read(51 *)
      read(51 *)m c m dn nr
      read(51 *)
      v2=v/v0

      do 1001 ii 1 nr
       read(51 *)
       r ad(51 *)
       read(51 *)rm nmm nnn
       read(51 *)
        rm 0 001*rm*nmm
        rm rm*(d*0 01)
       call dynmodel(v2 f dt nfile dp dq)
c converting into MW
        p p+(rm*dp)
        q q+(rm*dq)
1001      continue

      realp(i) p
      reactp(i) q

      endif
c             = =
      flag 0

171      continue
      close(41)
      close(42)
      close(49)
      close(51)

      return
      end
```

Appendix B

Dynamic modelling of induction motor

In the dynamic modelling of induction motor, the clasical model is taken and the swing equation is solved The equivalent circuit of induction motor is shown in Figure B 1

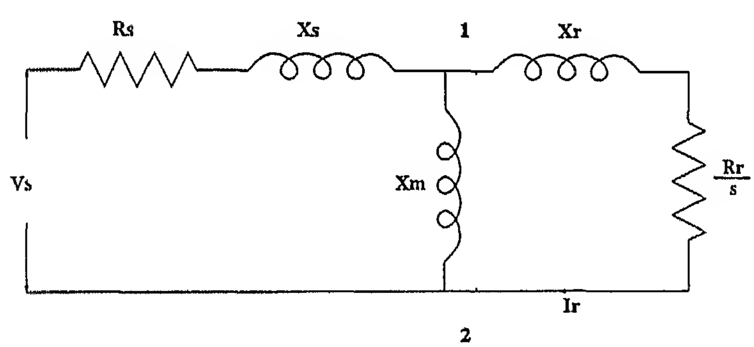

Figure B 1 Equivalent circuit of induction motor

After getting the Thevinin equivalent of the left of line 1-2 we have the circuit as shown in Figure B 2 This is true only if the supply voltage is strong, i e , V_s is an ideal voltage source

Here,

$$V_e = \frac{jX_mV_s}{R_s + j(X_s + X_m)} \tag{B 1}$$

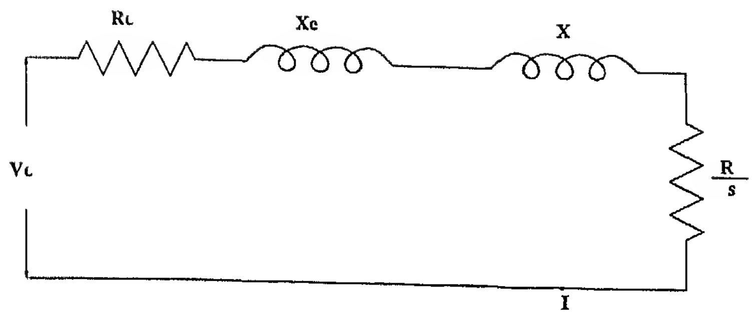

Figure B 2 Equivalent circuit of induction motor with Thevenin equivalent

$$R_e + jX_e = \frac{jX_m(R_s + jX_s)}{R_s + j(X_s + X_m)} \tag{B 2}$$

$$I_r = \frac{V_e}{(R_e + \frac{R_r}{s}) + j(X_e + X_r)} \tag{B 3}$$

The three phase electrical torque,

$$T_e = \frac{3}{2}P_f(\frac{I_r^{\,2}R_r}{s\omega_s}) \tag{B 4}$$

where P_f = number of poles in the motor

Substituting the value of I_r in the above equation

$$T_e = \frac{3}{2}P_f(\frac{R_r}{\omega_s - \omega_m})\frac{V_e^2}{(R_e + \frac{R_r\omega_s}{\omega_s - \omega_m})^2 + (X_e + X_r)^2} \tag{B 5}$$

Converting the angular frequencies ω_s and ω_m into mechanical units, i e

$\omega_s^m = \omega_s/(P_f/2)$ and $\omega_m^m = \omega_m/(P_f/2)$, we get

$$T_e = (\frac{3R_r}{\omega_s^m - \omega_m^m})\frac{V_e^2}{(R_e + \frac{R_r\omega_s^m}{\omega_s^m - \omega_m^m})^2 + (X_e + X_r)^2} \tag{B 6}$$

The swing equation for the motor is

$$\frac{d\omega_m^m}{dt} = \frac{1}{2H}(T_e - T_m) \tag{B 7}$$

The mechanical torque T_m

$$T_m = T_{m0}(A(\omega_m^m)^2 + B\omega_m^m + C) \tag{B 8}$$

where A, B and C are constants and are different for different motors

Substituting the values of T_e and T_m in the equation B 7, we get,

$$\frac{d\omega_m^m}{dt} = \frac{1}{2H}[(\frac{3R_r}{\omega_s^m - \omega_m^m})\frac{V_e^2}{(R_e + \frac{R_r\omega_s^m}{\omega_s^m - \omega_m^m})^2 + (X_e + X_r)^2}$$

$$-T_{m0}(A(\omega_m^m)^2 + B\omega_m^m + C)] \tag{B 9}$$

Equation B 9 is solved using Runge Kutta fourth order method

Appendix C

Computer code for the dynamic model of induction motor

```
c******  ******************************************************************
                              SUBROUTINE FOR
c                      DYNAMIC MODEL OF INDUCTION MOTOR
c*************************************************************** *****
      subroutin  dynm del(dvs df dt nfile dp dq)

      implicit none

      complex aa bb cc dd
      integer i nfile
      real dvs df dt ve
      real dp dpfrac dsf dpf
      real rs xs xm rr xr re xe pi
      real dh da db dc
      real wbs ws wm wm0 tm0 tm wm01 wm2 fff
      real k(4) a1 a2 a3 a41 a42 a4 a5 dq theta1

      tm 0 0
      wm 0 0

c          READIND DATA FOR INDUCTION MOTOR FROM FILE  d d
      read(nfile *)dp dpfrac dsf dpf
      read(nfile *)rs xs xm rr xr
      read(nfile *)dh da db dc

      pi=22 0/7 0

      wbs 2 0*pi*50 0
      ws 2 0*pi*df
c      -    wm01  IS THE VALUE OF  wm  AT FULL LOAD  AT 1 0 p u
c           VOLTAGE AND 50 0 Hz FREQ
      wm01 2 0*pi*50 0*(1 0 dsf)
c           wm0  IS THE INITIAL VALUE OF wm FOR THIS ITERATION
c      -   FROM NEXT ITERATION ONWARDS THIS INITIAL VALUE IS THE
c          VALUE OF  wm  OBTAINED AT THE END OF PREVIOUS ITERATION
c      -   WHICH IS REQUIRED TO BE IMPLEMENTED
      wm0 wm01
c      -   CONVERTING INTO BASE VALUES
      ws ws/wbs
      wm0 wm0/wbs
      wm01 wm01/wbs
      wm=wm0
```

```
      dp dp*dpfrıc
      tm0 dp/wm01

c           FINDING THEVENIN EQUIVALENT OF STATOR + MAGNETIC CIRCUIT
       a (0 0 1 0)
      bb=aa*xm*(r +(aa*xs))
      cc-rs aa*(xs+xm)
      dd-bb/cc
      r =real(dd)
      xe aımag(dd)
c           THEVENIN EQUIVALENT OF VOLTAGE
      ve ( a*xm*dvs)/(rs+aa*(xs+xm))

c         -  APPLYING RANGE KUTTA 4th ORDER METHOD
      do 100 i 1 4
      fff 0 0
            a1 1 0/(2 0*dh)
            a2 (3 0*rr)/(ws wm)
            a3 ve*ve
            a41 (re+(rr*ws)/(ws wm))
            a42 xe+xr
            a4 (a41*a41)+(a42*a42)

            wm2 1 0 (wm/wm01)
            a5 (da*wm2*wm2)+(db*wm2)+dc

            fff a1*(((a2*a3)/a4) (tm0*a5))

            k(i) dt*fff

            if ((i eq 1) or (i eq 2))then
                   wm wm+(k(i)/2 0)
            elseif(i eq 3)then
                   wm wm+k(i)
            endif
100         continue
c             RESTORING THE VALUES OF  wm  AND  tm
      wm wm0+(1 0/6 0)*( k(1) + 2 0*k(2) + 2 0*k(3) + k(4) )
      wm2 1 0 (wm/wm01)
      tm tm0*( da*wm2*wm2 + db*wm2 + dc )
      dp=tm*wm
      dsf (ws wm)/ws
      wm0 wm
      thetai acos(dpf)
      dq dp*tan(thetai)

      return
      end
```

Appendix D

Data and result files

```
********* ************************** ******************************

File      comp code

                    Total number of modells
                            28

        1         agriwp   AGRIcultural Water Pump

        2              arcfur   ACR FURnace

        3         centac   CENTral Air C nditioning

        4              cltdry   CLoThes DRYer

        5              cltwsr   CLoThs WaSheR

        6      cmceac   CoMmertial CEntral Air Conditi ning

        7       cmrmac   CoMmertial RooM Air Conditioning

        8              colrtv   COLouR TeleVision

        9            commhp   COMMertial Heat Pump

        10                dshwsr   DiSH WaSheR

        11                eltrys   ELecTRolYsiS

        12            flrlit   FLuoRescent LIghTing

        13                frez r   FREeZER

        14                furfan   FURnac  FAN

        15         hpceac   Heat Pump CEntral Air Conditioning

        16         hpcmac   Heat Pump CoMmertial Air Conditioning

        17              hpspht   Heat Pump SPace HeaTing

        18                inclit   INCandescent LIghTing

        19                lridlm   LaRge InDustriaL Motor
```

20	ordfan	ORDinary FAN
21	ordmtr	ORDınary M T R
22	rdpmp	ORDınary PuMP
23	pplaux	Power PLant AUXılıarı
24	refgtr	REFrıGeraT R
25	r pht	REsistanc SPace HeaT ng
26	r om c	ROOM Air Condıtıonıng
27	smıdlm	SMall InDustriaL M t r
28	wathtr	WATer H aT R

****

File load modelling

NUMBER OF LOAD BUSES AT WHICH LOAD MODEL SIMULATION IS REQUIRED
4

REFERENCE FREQUENCY Present frequency* Time step* * Used with tability program
50 0 50 0 0 05

BUS NO	REAL POWER	BASEVOLTAGE(of th bus KV/P U)
8	5 8	132 00
9	11 2	132 00
11	7 6	132 00
12	22 8	220 00
14	6 2	1 00
15	8 2	1 00
17	9 0	1 00
21	17 5	1 00
30	10 6	1 00

****

File load composıtion

Total loads of different models in MW
Total number of models 28 AREA BUS NO 8

MODEL NUMBER	MODEL LOAD (in MW)
1	1700
2	0774
3	3190
4	0029
5	0029
6	0455
7	0661
8	1119
9	0029
10	0000
11	0081
12	4379
13	0461
14	0197
15	0075
16	0044
17	0046
18	1 4947
19	3932
20	3492
21	1334
22	1331

```
   23              0625
   24              1450
   25              2378
   26              2842
   27              0196
   28              6369
 LOSSES                  3832958 MW
  T tal loads  f diff r nt m dels in MW
  Total numb r of m dels  28 AREA    BUS NO 9
  MODEL NUMBER     MODEL IOAD (in MW)
    1            1 2800
    2              1495
    3              6160
    4              0056
    5              0056
    6              4879
    7              1277
    8              2162
    9              0056
   10              0000
   11              0157
   12              8456
   13              0690
   14              0381
   15              0146
   16              0064
   17              0090
   18              9554
   19            1 7246
   20              6742
   21              2576
   22              2570
   23              7000
   24              2600
   25              4592
   26              2488
   27              1241
   26              8643
 LOSSES                  7401576 MW
and so on
```

****

File   s d

STATIC AND DYNAMIC BEHAVIOUR PERCENTAGE
NUMBER OF MODELS
28

MODEL NO	STATIC	DYNAMIC	EXPONENTIAL/POLYNOMIAL (stati)
1	100	0	e
2	100	0	
3	100	0	e
4	100	0	e
5	100	0	e
6	100	0	e
7	100	0	e
8	100	0	e
9	100	0	e
10	100	0	
11	100	0	e
12	100	0	e
13	100	0	
14	100	0	e
15	100	0	e
16	100	0	e
17	100	0	
18	100	0	e

19	100	0
20	100	0
21	100	0
22	100	0
23	100	0
24	100	0
25	100	0
26	100	0
27	100	0
28	100	0

*** ** *************** ******************* ************************

Fil mp cl ar

MODEL CHARACTERISTICS
STATIC AND EXPONENTIAL

NO	cod	POΓ	Pv	Pf	Qv	Qf	Nm	POFnm	P nm	Pfnm	Qvnm	Qfnm
1	agriwp	85	1 4	5 6	1 2	4 2	1 0	0 0	0 0	0 0	0 0	0 0
2	arcfur	72	2 3	1 0	1 61	1 0	0 0	0 0	0 0	0 0	0 0	0 0
3	c ntac	81	20	90	2 2	2 7	1 0	0 0	0 0	0 0	0 0	0 0
4	cltdry	99	2 0	0 0	3 3	7 6	20	1 0	0 0	0 0	0 0	0 0
5	cltwai	65	08	2 9	1 6	1 8	1 0	0 0	0 0	0 0	0 0	0 0
6	cmceac	75	10	1 0	2 5	1 3	1 0	0 0	0 0	0 0	0 0	0 0
7	cmrmac	75	50	60	2 5	2 8	1 0	0 0	0 0	0 0	0 0	0 0
8	colrtv	77	2 0	0 0	5 2	4 8	0 0	0 0	0 0	0 0	0 0	0 0
9	commhp	84	10	1 0	2 5	1 3	90	1 0	2 0	0 0	0 0	0 0
10	dshwar	99	1 8	0 0	3 5	1 4	80	1 0	2 0	0 0	0 0	0 0
11	eltrys	90	1 8	30	2 2	60	0 0	0 0	0 0	0 0	0 0	0 0
12	flrlit	90	1 0	1 0	3 0	2 8	0 0	0 0	0 0	0 0	0 0	0 0
13	frezer	84	80	50	2 5	1 4	80	1 0	2 0	0 0	0 0	0 0
14	furfan	73	08	2 9	1 6	1 8	1 0	0 0	0 0	0 0	0 0	0 0
15	hpceac	81	20	90	2 5	2 7	1 0	0 0	0 0	0 0	0 0	0 0
16	hpcmac	81	10	1 0	2 5	1 3	1 0	0 0	0 0	0 0	0 0	0 0
17	hpspht	84	20	90	2 5	1 3	90	1 0	2 0	0 0	0 0	0 0
18	inclit	1 0	1 54	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
19	lridlm	89	05	1 9	50	1 2	1 0	0 0	0 0	0 0	0 0	0 0
20	ordfan	87	08	2 9	1 8	1 8	1 0	0 0	0 0	0 0	0 0	0 0
21	ordmtr	87	08	2 9	1 8	1 8	1 0	0 0	0 0	0 0	0 0	0 0
22	ordpmp	87	08	2 9	1 8	1 8	1 0	0 0	0 0	0 0	0 0	0 0
23	pplaux	80	08	2 9	1 8	1 8	1 0	0 0	0 0	0 0	0 0	0 0
24	r fgtr	84	80	50	2 5	1 4	80	1 0	2 0	0 0	0 0	0 0
25	respht	1 0	2 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
26	roomac	75	50	80	2 5	2 8	1 0	0 0	0 0	0 0	0 0	0 0
27	smidlm	83	10	2 9	80	1 8	1 0	0 0	0 0	0 0	0 0	0 0
28	wathtr	1 0	2 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0

*************** ***

File out plot

To write the bus V P Q and total system P nd Q in individual files
Requirement of bus result out put in a file(Yes 1 No 0)
1
Requirement of out put files at all buses(Yes 1 N 0)
0
Number of buses if for limited buses is required
9

Serial Number	Bus Numbers	File Name
1	1	o 1
2	2	o 2
3	3	o 3
4	11	o 11
5	14	o 14
6	17	o 17
7	21	o 21
8	27	27

```
9                    30                    30

** * *********   *************** ***************  ****** **********

File      ut file names

o 1
o 2
  3
  4
o 5
o 6
  7
and s  on

 *************************************************** ********* ****

File     gen outag

Requirement  f grnerator outages or loss (Yes 1 N  0)
             0
Number of generators
       3
SL No        Bus   Itr   Loss Factor
1        4      5            0 0
2        5      6            0 0
3        6      6            0 0

*************************** *************************************

File     load outage

Requirement of load outages or loss (Yes 1 No 0)
            0
Number of loads
      3
SL N      Bus      Itr         Loss Factor
1         14        5              0 0
2         27        6              0 0
3         30        7              0 0

*******************************************************************

File     itr limit

LFP iteration limit
       20
LFP+LMP iteration limit
       30
Tolerence limit of voltage for convergence
               0 001
Requirement of varying tolerence limit of voltage(Yes=1 N  0)
                     0
Number of variations
        2
treation No           Tolerence limit
    15                         0 05
    25                         0 01

*************************************************** ***************

File     load mix change

Requitement of load mix change(Yes 1 No 0)
            1
Number of iterations
        15
          *    ***                 **   *   *
```

```
                ITR NO  1
Numb r of bus s   2
    Bu  and mod l number  in increa ing order
BUS NUMBER  8
Numb r of m del   2
Mod l  6          Load change  0 0
Model  28          Load change  0 0
BUS NUMBER  11
Numb r of mod ls  2
M d l  6          Load change  0 0
M d l  28          L ad chang   0 0
                =        -                  -
                ITR NO  2
Number of bus     2
    Bus and model numbers in incr asing ord r
BUS NUMBER  8
Numb r of models  2
M d l  6          Load change  0 15
Model  28          Load chang    0 15
BUS NUMBER  11
Number of models  2
Mod l  6          Load  hange  0 15
Model  28          Load change   0 15
                          =       =          =
and so  n
```

```
*********************************************************************

File      react loss

Requirem nt of mod lling of reactive loss in distribution(Yes 1 N  0)
                            1
Number of buses
     9
Bus no                     Reactive loss at 1 0 p u Voltage(MVAR)
  8                                       0 1
  9                                       0 35
  11                                      0 15
  12                                      1 2
  14                                      0 2
  15                                      0 3
  17                                      0 7
  21                                      0 3
  30                                      0 5

*********************************************************************

File      load increment

Requirement of load increment(Yes 1 No 0)
                1
Total iterations
      15
Requirement of pause(Yes 1 No 0)
              0
Iteration   Factor of load increment
   1             1 1
   2             1 1
   3             1 1
   4             1 1
   5             1 1
   6             1 1
   7             1 1
   8             1 1
   9             1 1
   10            1 1
   11            1 1
   12            1 1
```

```
   13             1 1
   14             1 1
   15             1 1
T  inc rase l ad at all bus  (Yes 1 No 0)
                      1
Numb r  f buses  t which load is to be increased
                      2
Bus num
12
21

******************************************* ************* **********

File      d d

************ ************** ******* ***********
MODEL CODE & NUMBER           NUMBER OF RATINGS
agriwp         1                     2
************ ************** *****************

            KW            NUMBER   dynm model numb r
            150 0           100             1

        1 0    1 0     0 05    0 80
        0 078  0 065   2 67    0 044   0 049
        0 4    0 01    0 01    1 0
                         -       -
            KW            NUMBER    dyn model number
            300 0           60             2

        1 0    1 0     0 05    0 80
        0 078  0 065   2 67    0 044   0 049
        0 4    0 01    0 01    1 0
*************************** * ******************
MODEL CODE & NUMBER           NUMBER OF RATINGS
centac         3                     2
***********************************************
                  -       -
            KW            NUMBER    dyn model numb r
            2 5            3000            3
                  -        --
        1 0    1 0     0 05    0 80
        0 078  0 065   2 67    0 044   0 049
        0 4    0 01    0 01    1 0
                          -
            KW            NUMBER     dyn model number
            5 0            1100              4
                -          -     -         -
        1 0    1 0     0 05    0 80
        0 078  0 065   2 67    0 044   0 049
        0 4    0 01    0 01    1 0

*************************************************************** ******

File      itr out1
In this the voltages  real and reactive powers at all buses
and total real and reactive power in the system and los es
are written for each load increment iteration

   -           ITR No   10   -
 Base MVA =  100 0  Pgen    2 9461
 Pload     2 79046  Losses =   1556332
 Bus N       V       Pinj       Qload
           (p u)    (p u)       (p u)
  1     1 0600    1 5498       4258
  2     1 0333      6981       1200
  3       9859      6981       1000
  4     1 0259      0000       2400
```

5	1 0100	0000	1528
6	1 0008	0000	2400
7	9773	0000	0000
8	9478	1168	0329
9	9672	2325	0981
10	1 0357	0000	3790
11	9767	1576	0487
12	9704	4751	2145
13	9748	0000	0000
14	9361	1236	0370
15	9307	1630	0507
16	9446	0698	- 0359
17	9372	1840	0813
18	9090	0638	0160
19	9032	1895	0678
20	9125	0439	0140
21	9290	3559	1555
22	9314	0000	0000
23	9213	0638	0319
24	9275	1735	0479
25	9630	0000	0000
26	9456	0696	0459
27	9913	0479	0239
28	9735	0000	0000
29	9911	0479	0180
30	9636	2119	0561

ITR No 11 -

****

File itr out2
In this the voltage real and reactive pow rs at the modelled buses
is written for each LFP+LMP run

ITN	BUS NO	VOLTAGE (KV)	P (MW)	Q (MVAR)
*********** BASE LOAD CONDITION ************				
		(LFP + LMP) ITR	1 -	-
1	8	1 0347	6 0187	1 9742
1	9	1 0493	11 6307	5 6877
1	11	1 0247	7 8117	2 6965
1	12	1 0085	22 9410	11 4775
1	14	1 0351	6 4268	2 2304
1	15	1 0319	8 4680	3 0893
1	17	1 0298	9 1822	4 8043
1	21	1 0252	17 8018	9 2423
1	30	1 0514	11 0657	3 3747
		(LFP + LMP) ITR	2 --	-
2	8	1 0365	6 0304	1 9816
2	9	1 0501	11 6376	5 6956
2	11	1 0240	7 8055	2 6926
2	12	1 0078	22 9294	11 4640
2	14	1 0346	6 4237	2 2265
2	15	1 0320	8 4686	3 0697
2	17	1 0321	9 1963	4 6235
2	21	1 0276	17 8306	9 2606
2	30	1 0413	10 9330	3 3056
		(LFP + LMP) ITR	3 ----	--
3	8	1 0365	6 0302	1 9814
3	9	1 0501	11 6378	5 6955
3	11	1 0241	7 8058	2 6927
3	12	1 0079	22 9299	11 4646
3	14	1 0346	6 4238	2 2285
3	15	1 0320	8 4686	3 0697
3	17	1 0320	9 1960	4 8232

```
  3    21          1 0276      17 8301       9 2799
  3    30          1 0421      10 9439       3 3114

********** LOAD INCREMENT ITR    1 ************

         (LFP + LMP) ITR    1
  1     8          1 0316       6 6417       2 1579
  1     9          1 0468      12 8511       6 2293
  1    11          1 0212       8 6156       2 9452
  1    12          1 0052      25 3396      12 5536
  1    14          1 0297       7 0759       2 4292
  1    15          1 0266       9 3261       3 3646
  1    17          1 0267      10 1448       5 2564
  1    21          1 0217      19 6622      10 1042
  1    30          1 0369      12 0422       3 6038
         (LFP + LMP) ITR    2    -
  2     8          1 0318       6 6432       2 1589
  2     9          1 0469      12 8523       6 2306
  2    11          1 0213       8 6159       2 9454
  2    12          1 0052      25 3402      12 5543
  2    14          1 0298       7 0772       2 4300
  2    15          1 0268       9 3279       3 3658
  2    17          1 0269      10 1463       5 2585
  2    21          1 0219      19 6656      10 1087
  2    30          1 0373      12 0474       3 6065

********** LOAD INCREMENT ITR    3************
and so on
```